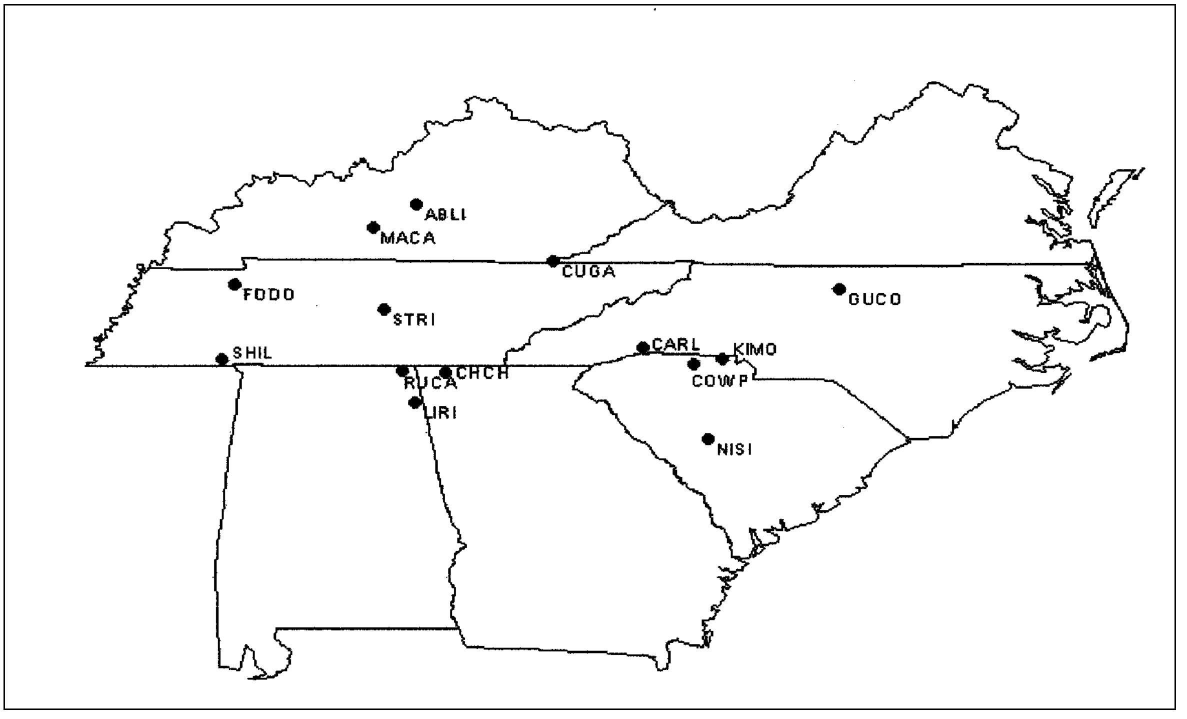
Phase I: Vital Signs Monitoring Plan
Cumberland Piedmont Network

September 2002



<u>Cumberland Piedmont Network</u>

Abraham Lincoln Birthplace National Historic Site (ABLI)
Carl Sandburg Home National Historic Site (CARL)
Chickamauga and Chattanooga National Military Park (CHCH)
Cowpens National Battlefield (COWP)
Cumberland Gap National Historical Park (CUGA)
Fort Donelson National Battlefield (FODO)
Guilford Courthouse National Military Park (GUCO)
Kings Mountain National Military Park (KIMO)
Little River Canyon National Preserve (LIRI)
Mammoth Cave National Park (MACA)
Ninety Six National Historic Site (NISI)
Russell Cave National Monument (RUCA)
Shiloh National Military Park (SHIL)
Stones River National Battlefield (STRI)

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Introduction

The National Park Service (NPS) mission, to preserve, protect, and maintain the health of park ecosystems for the enjoyment of future generations, relies upon access to science-based information regarding the status and trends of ecosystem health. Parks have a critical need to know the condition of natural resources in order to meet the basic goal of preservation. To address this need, the NPS implemented a new strategy to conduct a servicewide Inventory and Monitoring (IM) program. There are three major components of the IM strategy: (1) completion of basic resource inventories; (2) creation of prototype long-term ecological monitoring programs; and (3) implementation of operational monitoring of critical parameters.

As part of the strategy to achieve the goals and objectives of the IM program, the National Park Service grouped parks into 32 networks. Networks comprise parks having similar resources and management issues, and represent an organized approach to reduce costs, ensure consistent products, and increase information exchange. Each network has completed a plan to conduct biological inventories and is now designing an integrated monitoring program. The five basic goals of the monitoring program are to:

I. Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
II. Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
III. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
IV. Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.
V. Provide a means of measuring progress towards performance goals.

The recommended approach for networks in developing their monitoring strategy involves three phases. Due dates are shown for the first group of funded networks:

PHASE I: due October 1, 2002

- ♦ Form a network Board of Directors and Technical Committee
- ♦ Compile and summarize existing data, significance of park natural resources, important management issues, and current/past monitoring activities.
- ♦ Determine potential indicators for monitoring by the development of conceptual models that describe the interactions of stressors and effects within the relevant ecosystems.
- ♦ Define monitoring goals and objectives

PHASE II: due April 1, 2003

- ♦ Select indicators for monitoring with specific measurable objectives, thresholds, and management actions.

PHASE III: due April 1, 2004

- ♦ Draft the monitoring strategy including: sampling design, protocols, data management, analysis, and reporting, staffing, scheduling, and budget.
- ♦ Complete the Network Monitoring Plan for review and approval.

This report summarizes activities completed during Phase I of the Monitoring Plan.

Background for Cumberland Piedmont Network

The Cumberland Piedmont Network (CPN) contains 14 parks with diverse cultural and natural resources that span seven states and cover 107,260 acres. There are four historic parks, four Revolutionary War parks, four Civil War parks, one national preserve, and one national park. They range in size from a couple hundred acres to over 50,000 acres and lie in six different physiographic regions. The largest of these is Mammoth Cave National Park, a World Heritage Site that constitutes the core area of an International Biosphere Reserve. Mammoth Cave is also a prototype long-term ecological monitoring (LTEM) park for the NPS cave and karst biome category. Prototype parks provide guidance on the design, development, and testing of monitoring protocols. The other 13 CPN parks are expected to work together, with guidance from Mammoth Cave and other LTEM programs, to prepare a monitoring program that will accomplish the five basic goals of the Inventory and Monitoring program. The partnership between CPN and MACA-LTEM resulted in the CPN Water Quality Monitoring Plan, which is attached to this report as Appendix E and the Quality Assurance Plan as Appendix F. The water quality plan was prepared by Joe Meiman, hydrogeologist with over 10 years experience monitoring the waters at Mammoth Cave National Park.

Who Benefits?

The target beneficiary of the CPN monitoring program is the park resource manager. Managers need the ability to detect significant changes in resource condition and to evaluate potential management responses. If enough is known about the ecosystem (cause-and-effect is established), thresholds that trigger management actions will be defined. Where information is limited (cause-and-effect is not established), the monitoring data will generate research questions that require more intensive study. Beyond park-level resource management, the NPS as an agency will benefit from a standardized approach of planning and design in order to report on the Service's performance goals. For the first time, inventory and monitoring data will be coordinated through the Networks to achieve an agencywide status of park resources. Another important opportunity of network monitoring, beyond the benefits to NPS, is to contribute data to a larger regional or landscape level need. Many agencies are already monitoring amphibians, birds, species and communities of concern, water quality, and air quality. Some issues, such as air quality, concern the entire region. Our ability to document impacts in a group of parks that span seven states, has much greater significance than at one or two parks. The NPS Network IM program will greatly supplement these state and regional efforts and help build partnerships that are critical to the overall preservation of ecosystem health.

Board of Directors

In January 2001, the CPN established a charter during a meeting of parks held at Mammoth Cave National Park. A Board of Directors, comprised of five park superintendents and the regional IM Coordinator, was selected to oversee the development of the monitoring strategy for the network. The Board makes decisions regarding the development and implementation of the monitoring strategy, including hiring, budgeting, and scheduling, and promotes accountability for the monitoring program. The Board is chaired by Ronald R. Switzer, Superintendent of Mammoth Cave National Park, and includes: Connie Backlund, Superintendent of Carl Sandburg National Historic Site, Stuart Johnson, Superintendent of Stones River National Battlefield, Bill Springer, Superintendent of Little River Canyon National Preserve, Mark Woods, Superintendent of Cumberland Gap National Historical Park, and Larry West, Southeast Regional IM Coordinator.

Coordinator and Technical Committee

In August 2001, a Network Coordinator, Teresa Leibfreid, was hired and duty-stationed at Mammoth Cave National Park. The Network Coordinator is responsible for the development, management, and operation of the network, with oversight and supervision by the Southeast Region IM Coordinator, Larry West. A technical committee was formed to provide technical assistance and advice to the Board of Directors. This committee is made up of natural resource managers and scientists that serve as reviewers to evaluate conceptual designs, monitoring strategies, and ecological relevance of proposals. The committee also participates in the development of annual work plans and budgets.

Goals and Objectives

As listed in the introduction, there are five Servicewide IM goals. Three deal directly with ecosystem condition and two with legal mandates and performance management. These are the same goals that will drive the CPN IM program, which is funded by an annual program base of $476,700. In order to meet these goals for 13 parks (not including Mammoth Cave NP which is funded by LTEM program), it will be necessary to seek additional funds and support from other sources. In fact the entire funding base could easily be spent on legal mandates and performance management goals alone. In the CPN, nine parks contain federally listed species and all fourteen have invasive exotics. Three are required to report on condition of water quality and two are required to report on air quality.

Although most were established for the preservation of cultural resources, all CPN parks contain significant natural resources such as the limestone glades found at Chickamauga and Stones River National Battlefields, a pristine bog at Cumberland Gap National Historical Park, caves at Russell Cave National Monument, Lookout Mountain, and Mammoth Cave National Park, prairie remnants at Cowpens National Battlefield, and nationally significant waters found at Little River Canyon National Preserve and Mammoth Cave National Park (for a summary of park natural resources, see Appendix A). The preservation of all resources is part of the NPS mission, with specific statements regarding Inventory and Monitoring embedded in management policies and legislation (see Table 1).

The CPN challenge, as with other networks, involves allocating limited resources among the various goals and parks. Our approach thus far in Phase I was to gather data on "what to monitor" from two main sources: 1) all parks provided input on significant resources and management issues, current/past monitoring activities, and 2) a team of interdisciplinary scientists provided scientific input through the development of draft ecosystem conceptual models. In Phase II, the CPN will take these results and formulate a ranking matrix similar to those used in other parks, networks and LTEMs, and form a special workgroup made up of scientists and park managers to prioritize and select the "Vital Signs". Once selected, the full design will include data management and sampling protocols, which will be developed in Phase III.

Regardless of which "vital signs" are funded, the CPN plans to assist parks with other critical monitoring needs by helping define measurable objectives and helping provide data, where possible (ie.,easily attainable, no sampling required) to monitor changes (see Table 6 "Preliminary CPN Objectives). Some parks have made great strides toward development of monitoring goals, but many still need assistance to meet legal mandates and basic performance management goals. Management objectives should include information on six components: 1) what will be monitored (species/habitat indicator); 2) location (geographical area); 3) attribute (e.g. size, density, cover); 4) action (e.g., increase, decrease, maintain); 5) measurable state or degree of change for the attribute; and 6) time frame needed for management action to prove effective (Elzinga et al. 1998).

> ***Example Management Objective:*** *To maintain the 90% open area of glades that are greater than 1200 square meters within Stones River National Battlefield. The recommendation is to monitor at an interval of five to ten years for detecting biologically meaningful changes.*

A good measurable sampling objective includes level of confidence and precision, such as in this example proposed by The Nature Conservancy for monitoring calcareous glades at Stones River National Battlefield (Hogan et al. 1996):

> ***Example Woody Cover Monitoring Objective:*** *Be 90% sure of detecting a 10% increase in woody cover and accept a 10% chance of falsely concluding that a change has taken place when it has not. The recommendation is to monitor at an interval of five to ten years for detecting biologically meaningful changes.*
>
> ***Example Management Action:*** *If a biologically significant increase (10%) in the cover of woody species has occurred, implement appropriate management to lower woody cover.*

The specific measurable objectives for CPN will be defined once indicators are selected during Phase II.

Table 1: Summary of NPS Legislation and Policy related to Inventory and Monitoring

Legislation	Significance to Inventory and Monitoring
NPS Management Policies 2001	"*The Service will: Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents.* *Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship, and identify the processes that influence those resources.* *Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals.* *Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames. Use the resulting information to maintain-and, where necessary, restore-the integrity of natural systems.*"
NPS Management Policies 2001 related to Endangered Species Act, 1973, amended 1988	*Undertake active management programs to inventory, monitor, restore, and maintain listed species' habitats, control detrimental non- native species, control detrimental visitor access, and re- establish extirpated populations as necessary to maintain the species and the habitats upon which they depend.* *Manage designated critical habitat, essential habitat, and recovery areas to maintain and enhance their value for the recovery of threatened and endangered species.* *Cooperate with other agencies to ensure that the delineation of critical habitat, essential habitat, and/ or recovery areas on park- managed lands provides needed conservation benefits to the total recovery efforts being conducted by all the participating agencies.* *The National Park Service will inventory, monitor, and manage state and locally listed species in a manner similar to its treatment of federally listed species, to the greatest extent possible. In addition, the Service will inventory other native species that are of special management concern to parks (such as rare, declining, sensitive, or unique species and their habitats) and will manage them to maintain their natural distribution and abundance.*
National Parks Omnibus Management Act of 1998	*The Secretary shall undertake a program of inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources. The monitoring program shall be developed in cooperation with other Federal monitoring and information collection efforts to ensure a cost-effective approach*"
National Park Service Organic Act, 1916	The mission of the National Park Service is "*...to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations*"
NEPA 1969	Requires certain knowledge of resource conditions to direct and evaluate effects of management actions.
Forest & Range land Renewable Resources Planning Acts of 1974 and 1976	Express Congressional insistence on inventory and monitoring of natural resources on all public lands in the U.S.
Executive Order 13186 to Protect Migratory Birds 2001	Federal agencies shall... *"promote research and information exchange related to the conservation of migratory bird resources, including coordinated inventorying and monitoring and the collection and assessment of information on environmental contaminants and other physical or biological stressors having potential relevance to migratory bird conservation."*
Other Acts	Fish and Wildlife Coordination Acts, 1958 and 1980; Migratory Bird Treaty Act, 1974; Clean Water Act; Executive Order 11900 (Protection of Wetlands); and the Clean Air Act.

Summarizing Existing Data and Holding the Workshops
One of the more important steps in developing a monitoring strategy is identifying, summarizing, and evaluating the existing information on park ecosystems. To accomplish this step: 1) literature and management plans for each park were reviewed, 2) existing datasets and current monitoring were summarized (Appendix B), and 3) resource management issues were ranked (Appendix C). Due to the inactive status of many Resource Management Plans, park managers were asked (by electronic survey) to prioritize management issues. The gathered data were then presented at a series of three workshops by park staff and subject-matter experts. Mammoth Cave National Park hosted a fourth workshop specific to their Long-term Ecological Monitoring Program. The fifth and final workshop was held jointly with the Appalachian Highlands Network to develop conceptual models. (Table 2)

The purpose of the first three workshops was to give an overview of the IM Network strategy, to identify significant natural resources, to prioritize park management issues, and to identify monitoring needs. The three CPN workshops were attended by a variety of park staff including: Historians, Curators, Resource Managers, Chief Rangers, Chief of Operations, Chief of Visitor Use, and Superintendents. Each park presented their significant natural resources on the first day and discussed management issues on the second.

Table 2: CUMBERLAND PIEDMONT NETWORK FY02 WORKSHOPS

DATE/PLACE	*PARKS*	*PARTICIPANTS*	*PURPOSE*
January 30-31, 2002 at Kings Mountain, NC	Carl Sandburg Home NHS Cowpens NB Guilford Courthouse NMP Kings Mountain NMP Ninety Six NHS	Park Staff, Subject Matter Experts:Air, Water,Fire, Exotics, CESU, NatureServe, SER-IM Coordinators, Appalachian Highlands Network Coordinators	Identify Significant Resources, Prioritize Management Issues, Identify Monitoring Needs
March 26-27, 2002 at DeSoto State Park, AL	Chickamauga and Chattanooga NMP Little River Canyon Russell Cave NM Shiloh NMP	Park Staff, Subject Matter Experts:Air, Water,Fire, Exotics, CESU, NatureServe, FWS, SER-IM, Appalachian Highlands Network Coordinators	Identify Significant Resources, Prioritize Management Issues, Identify Monitoring Needs
May 1-2, 2002 at Mammoth Cave National Park, KY	Abraham Lincoln Birthplace NHS Cumberland Gap NHP Fort Donelson NB Stones River NB	Park Staff, Subject Matter Experts:Air, Water,Fire, Exotics, CESU, NatureServe, SER-IM, CPN, Appa Highlands Network Coordinators	Identify Significant Resources, Prioritize Management Issues, Identify Monitoring Needs
May 15, 2002 at Mammoth Cave National Park, KY	Mammoth Cave NP- Long Term Monitoring Program	Park Staff, USGS-BRD, University of Tenn, CPN Coordinator	Identify Significant Resources, Prioritize Management Issues, Identify Monitoring Needs
July 17-18, 2002 at Great Smoky Mountains Learning Center, NC	Big South Fork NRRA Blue Ridge Parkway Great Smoky Mtns NP Mammoth Cave NP Obed River	Park Staff, University Staff, FWS, SAMAB, NRCS, USGS-BRD, CESU, Gulf Coast/ Appa Highlands/ CPN Coordinators	Develop Conceptual Models

Significant Natural Resources in the Cumberland Piedmont Network
Four categories (indicated below in Table 3) were chosen to group significant natural resources. The information for each park is summarized by category.

<u>Category 1: Natural Resources significant to enabling legislation</u>
The enabling legislation for twelve of the fourteen CPN parks provides for the preservation of the cultural resources and commemoration of Civil War and Revolutionary War battles. Though natural resources are not

specifically mentioned, they are tied to enabling legislation due to their significance in the interpretation of the historic landscapes (e.g., battlefield, home, farm, cave). For example, an account of the second day of battle at Chickamauga in 1863, mentions one of their most significant natural resources, calcareous glades: *"After advancing in line of battle for a few hundred yards through a piece of woods we emerged from the woods into an open glade, or meadow-like piece of ground, almost entirely free from all undergrowth. Here we encountered the enemy's line of skirmishers or sharpshooters."* (Report by Captain Joseph S. Cone, 47th Georgia Infantry, in Scott 1890).

Some parks have Cultural Landscape Plans and Reports that provide details for restoration and maintenance that relate specifically to natural resources. For example at Kings Mountain National Military Park, the Cultural Landscape Report recommends: *"rehabilitating the natural/cultural landscape by re-establishing the ridge top's open space and historic views. Managing the vegetation to maintain the cleared area, vistas, and the open understory of the wooded slopes is recommended."* (Vincent 1999)

Parks that do have specific natural resources mentioned in enabling legislation are: Abraham Lincoln Birthplace (sinking spring), Mammoth Cave National Park (cave,water,forest), Little River Canyon (river,canyon), and Russell Cave National Monument (cave).

Table 3: WORKSHEET FOR IDENTIFYING SIGNIFICANT NATURAL RESOURCES

PARK	NATURAL RESOURCES SIGNIFICANT TO ENABLING LEGISLATION	NATURAL RESOURCES SIGNIFICANT TO LEGAL MANDATES/POLICY	NATURAL RESOURCES SIGNIFICANT TO PERFORMANCE MANAGEMENT GOALS	NATURAL RESOURCES SIGNIFICANT FOR OTHER REASONS
ABLI	Sinking Spring, Knob Creek. Cultural landscape of 1808-1816	Sinking Spring Cave, Wetlands, State listed species, Exotic species	Exotics, Vital Signs	Old growth forest, rock shelters, cave species, glades, biodiversity at Knob Creek, Birds
CARL	Cultural landscape of 1945-1967 "wildness"	Wetlands, State listed species, Exotic species	Exotics, Vital Signs, Cultural landscape	G2 Appalachian Low Elevation Granitic domes. Birds, Beaver
CHCH	Battlefield landscape of 1863	Federally listed species: Mountain Skullcap and Gray Bat. State listed Species. Caves	Exotics, Vital Signs TandE	Cedar Glades, Deer, Birds,Southern Pine Beetle
COWP	Battlefield landscape of 1781	Federally listed species: dwarf-flowered heartleaf, State listed Species, Wetlands, Exotic species	Exotics, Vital Signs, TandE, Air Quality, Cultural landscape	Deer, Birds, Nonvascular plants
CUGA	Cultural Landscape pre-history through Civil War. Geologic formations	Federally listed species:Black side dace, Indiana bat, proposed wilderness, caves, State listed Species, wetlands, Exotic species	Exotics, Vital Signs, Water quality, TandE	Limestone cliffs, rock shelters, elk?, forest pests, G1 Forest Community, Birds
FODO	Battlefield landscape of 1862	Federally listed species: Price's Potato Bean, State listed species, Wetlands, Exotic species	Exotics, Vital Signs, TandE	Earth works vegetation, Birds
GUCO	Battlefield landscape of 1781	Wetlands, Exotic species (No known state/federally listed species)	Exotics, Vital Signs, Cultural landscape	G3 Piedmont Small Stream Sweetgum Forest. G3G4 Acidic Piedmont Mesic Mixed Hardwood Birds
KIMO	Battlefield landscape of 1780.	Federally listed species: Georgia Aster, Wetlands, State listed species, Exotic species	Exotics, Vital Signs,Cultural landscape, TandE	Macroinverts? (inventory is needed) Birds
LIRI	River and Canyon	Outstanding National Resource Water (ONRW), Wetlands, Federally listed species(3 plants,1fish), State listed Species, Exotic species	Water Quality, Vital Signs, Exotics, TandE	Sandstone Glades, Green Pitcher bog, Terrace-Riparian communities, Riffles and Shoals, Birds
MACA	Rivers, cave streams, cave formations,forests,	Federally listed: 7 mussels, 2 bats, 1 bird, 1 cave shrimp, 1 fish (historic), 1 dragonfly, and 1 plant, Caves, Outstanding National Resource Waters (surface and cave), Wild and Scenic	Water quality, Aquatic ecosystem health, Exotics, Disturbed lands, Air Quality, TandE species, Vital	Biodiversity of: surface aquatic, cave aquatic, surface terrestrial, soils, and cave terrestrial ecosystems. Undisturbed forest. "Big Woods" (300 acres of old growth), glades, bogs, river islands, sinkholes, hemlock hollows, barren

Table 3: WORKSHEET FOR IDENTIFYING SIGNIFICANT NATURAL RESOURCES				
PARK	***NATURAL RESOURCES SIGNIFICANT TO ENABLING LEGISLATION***	***NATURAL RESOURCES SIGNIFICANT TO LEGAL MANDATES/POLICY***	***NATURAL RESOURCES SIGNIFICANT TO PERFORMANCE MANAGEMENT GOALS***	***NATURAL RESOURCES SIGNIFICANT FOR OTHER REASONS***
		River, Wetlands, Class I Airshed, State listed and Exotic species.	Signs.	remnants, upland swamps, sandstone/limestone cliff-lines, and cave entrance ecotones.]
NISI	Battlefield landscape of 1781	State listed species, Wetlands, Exotic species	Exotics, Vital Signs, Cultural landscape	Swampy woods/wetlands, Lake, Deer, Fire ants, Coyote, Birds,
RUCA	Cave, Cultural Landscape of 7000 BC to 1600 AD	Cave State listed Species, Exotic species	Vital Signs, Exotics	Biodiversity of cave ecosystem, Birds, Rare Bryophytes.
SHIL	Battlefield Landscape of 1862	Federally listed species 1 bird, 2 bats, 2 inverts, State listed species, Exotic species	Water Quality. Vital Signs, Exotics	Endemic Lichen, Birds, High Biodiversity in Aquatic Community, Hardwood Bottomland Forest, New Land Acquisition, Deer, Beaver
STRI	Battlefield landscape of 1862-1866	Federally listed species: Tenn Coneflower, 303d Water, cave, State listed species, Exotic species	Exotics, Disturbed lands, Vital Signs, Water Quality	Earth work restoration, cedar glades, deer & groundhog problems, Birds

Category 2: Natural Resources significant to legal mandates/policy

In this group, CPN has nine parks with federally listed plants, four parks with federally listed bats, two with federally listed fish, one with federally listed mussels and cave shrimp. More federally listed species may be discovered during the biological inventories that are underway during 2002-05. CPN has five parks with caves, several needing survey and biological inventory and many parks contain wetlands that have not yet been officially delineated. Mammoth Cave and Little River Canyon both have water resources designated as "Outstanding National Resource Waters". Mammoth Cave NP is also designated as an International Biosphere Reserve and contains a "Wild and Scenic River".

Category 3: Natural Resources Significant to performance management goals

All 14 CPN parks have invasive exotic plant species, nine parks have federally listed species, three parks have required water quality monitoring(Stones River with 303d status, Mammoth Cave and Little River Canyon with "Outstanding National Resource Waters") Two parks are monitoring Air Quality: Mammoth Cave and Cowpens (Table 4).

Table 4. Performance Management Goals related to Inventory and Monitoring	
NPS Strategic Plan Mission Goals	**Cumberland Piedmont Network**
Ia1. Disturbed Lands / Exotic Species – 10.1% of targeted disturbed park lands are restored, and exotic vegetation on 6.3% of targeted acres are contained.	All CPN parks have invasive exotics only a few have disturbed lands.
Ia2. Threatened and Endangered Species – 14.4% of the 1999 identified park populations of federally listed threatened and endangered species with critical habitat on park lands or requiring NPS recovery actions have improved status, and an additional 20.5% have stable populations.	Nine parks have federally listed species, but not all have critical habitat and not all species require NPS recovery actions
Ia3. Air Quality -- Air quality in 70% of reporting park areas has remained stable or improved.	COWP and MACA are currently monitoring air quality
Ia4. Water Quality – 75% of 288 parks have unimpaired water quality	All CPN parks. MACA and LIRI have ONRW status and STRI has 303d status
Ia7. Cultural Landscapes – 35% of the cultural landscapes on the Cultural Landscape Inventory with condition information are in good condition.	Only a few CPN parks have Cultural Landscape Inventory completed
Ib1. National Resource Inventories – Acquire or develop 87% of the 2,527 outstanding data sets identified in 1999 of basic	All CPN parks

Table 4. Performance Management Goals related to Inventory and Monitoring	
NPS Strategic Plan Mission Goals	**Cumberland Piedmont Network**
natural resource inventories for all parks.	
Ib3. Vital Signs – 80% of 270 parks with significant natural resources have identified their vital signs for natural resource monitoring	All CPN parks
Ib5. Aquatic Resources – NPS will complete an assessment of aquatic resource conditions in 265 parks	All CPN parks

Category 4: Natural Resources Significant for other reasons

Several parks have globally significant species and communities according to ranks designated by The Nature Conservancy. As the vegetation mapping and biological inventories progress, we can fully document these occurrences. New discoveries include: G1 forest type at Cumberland Gap, a G2 granitic dome at Carl Sandburg, a G2/G3 glade at Chickamauga, and a G3 forest type found at Guilford Courthouse (NatureServe pers.comm.). The current count of Globally Significant species for the Network: five G1s, forty-three G2s, eighty G3s, and three G4s (NPSpecies database). These are summarized in Table 5.

Table 5: Globally ranked CPN Species			
TNC Global Rank	**#CPN Species**	**Status**	**Description**
G1	5	Critically Imperiled	Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000) or acres (<2,000) or linear miles (<10).
G2	43	Imperiled	Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50).
G3	80	Vulnerable	Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
G4	3	Apparently Secure	Uncommon but not rare (although it may be rare in parts of its range, particularly on the periphery), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals.

Significant Management Issues

Approximately two weeks prior to each workshop, parks were asked to rank and comment on management issues using the standard list from National Park Service Resource Management Plan Guidelines 1994. They were given an opportunity to add issues and were also asked to complete a table of current monitoring activities. During the workshops, management issues were discussed and the attendees were asked to identify the "resources impacted", "management questions", "potential indicators", and "potential management actions". For a summary of the management issues for four workshops, see Appendix C. To obtain an in-depth assessment of a few high-priority issues, workshop presentations included CPN-specific summaries by the following subject-matter experts:

1) Air Resources Summary, by Tonnie Maniero, Air Resources Division, Appendix D
2) Water Resources Summary, by Joe Meiman, Hydrologist Mammoth Cave National Park, Appendix E
3) Exotic plants, by Joe Rogers/Kris Johnson, Great Smoky Mountains National Park
4) Fire Monitoring, by Bob Dellinger/Caroline Lansing, NPS-Fire program
5) Bird Conservation Plans, by Keith Watson, FWS
6) Terrestrial Communities of Concern, by Rickie White, NatureServe

The top eleven management issues based on park-input are listed in Table 6. Using ranks of "High, Medium, Low" the issues are ordered by the number of parks ranking each issue "High". (These issues are summarized in the section on Conceptual Models). Many of the top issues already have existing data and partners, and the main task is to organize, analyze, and report on for the Network parks. Take the top ranked issue of Adjacent Landuse Impacts. Many states have extensive landuse data gathered over the years through programs such as GAP, EPA-MRLC, etc.. The CPN plans to include two components: park-scale and regional-scale. For park-scale issues, such as adjacent development and agriculture, the area of interest will be defined (e.g., watershed, surrounding counties,) and the analysis of change will be GIS based.

> ***Example Management Objective:*** *To measure the % area change of landuse categories that are biologically significant to water quality within the watershed of Little River Canyon National Preserve. The recommendation is to monitor at an interval of x years for detecting meaningful changes.*
>
> ***Example Monitoring Objective:*** *No sampling is required for this management objective.*
>
> ***Example Management Action:*** *If % change of any landuse category that impacts resources is greater than x%, monitoring for impacts to that resource will be evaluated.*

Obviously, there are questions to answer: What types of landuse change are biologically significant to the ecosystem? At what percent and at what time interval should they be measured? Management and monitoring objectives will take some time and research to quantify. Meanwhile, the CPN will gather and organize the data layers for parks as discussed in Table 6 under "Preliminary CPN Objective".

For regional-scale issues such as air quality, data could be summarized at the network level building upon the air resources summary completed by Maniero (Appendix D). Existing and new monitoring sites need evaluation to determine if nearby parks can use data (Pers. Comm. Maniero 2002). Another example, as point sources of pollutants enter or exit the region, the CPN could easily track changes through GIS-layers and provide a periodic report to the parks on how the surrounding environment is changing. The same holds true for the spread of invasive exotics, forest pests, and other stressors that are mappable. Overtime, these changes could be linked to impacts on ecosystem health. As stated earlier, many agencies are already gathering this data and the CPNs main role will be to summarize it for the network. Data and summary reports generated by initiatives like EPA's "State of the Environment Report" will include: human health, ecological condition, clean air, pure water, and better-protected land. For regional changes in forest ecosystems, data from initiatives like the USFS "Southern Forest Resource Assessment" (Wear and Greis 2001) can be used. Many of the plots used for Forest Inventory Analysis and Forest Health Monitoring are on or very near park lands. The timing of the adjacent landuse/regional environment analysis and reports would be driven by the rapidity of change and availability of data.

The biological effects upon park ecosystems will be addressed by a combination of network Vital Signs monitoring, LTEM, and research. Indicators will be chosen based on conceptual models of the ecosystem and park input(see conceptual model section below). The selection process for Vital Signs will be initiated in Phase II of the network monitoring program.

Table 6: High priority management issues					
Management Issue	**IM Goal**	**Park Rank**	**Management Question**	**Preliminary CPN Objective**	**Partners**
ADJACENT LANDUSE IMPACTS	I,II?,III	12-HIGH 2-MED	How is adjacent landuse changing ?	Prepare GIS layers based on existing data and standards for evaluation of landuse change.	State Agencies, EPA, USGS
EXOTIC PLANT MANAGEMENT	II?, III, IV, V	11-HIGH 3-MED	Are exotic plants spreading to new areas of park? Are new exotics approaching?	Coordinate with EPMT to map existing exotics and document encroachment in NpSpecies	Exotic Plant Management Team, State Exotic Pest Councils
THREATENED AND ENDANGERED SPECIES MANAGEMENT	II?,III,IV, V	10-HIGH 2-MED 1-LOW 1-UNK	Is current monitoring adequate and are data being managed to detect trends?	Evaluate current monitoring of TandE species to document protocols and incorporate dataflow into NRTemplate	FWS, NatureServe, State Heritage Programs
FIRE MANAGEMENT	II?,III,IV	9-HIGH 3-MED 1-LOW 1-UNK	Are fuels building up enough to pose a serious threat to resources?	Coordinate with Fire Program to incorporate fuels data into current or planned field activities	Fire Program, SERO, Univ of GA, NatureServe
WATER RESOURCES MANAGEMENT	ALL	8-HIGH 4-MED 2-UNK	Is water quality impaired per designated use standards?	Implement the CPN-Water Quality Monitoring Plan. Coordinate with MACA hydrologists to begin sampling in FY03	MACA-LTEM, WRD
NATIVE TERRESTRIAL PLANT MANAGEMENT	I, II?,III	7-HIGH 4-MED 1-LOW 2-UNK	What are the major vegetation types, their distribution, and condition?	Continue vegetation mapping project and documentation of significant communities.	NatureServe Univ of GA
AIR RESOURCES MANAGEMENT	ALL	7-HIGH 3-MED 2-LOW 1-UNK	Are high levels of ozone impacting park resources?	Coordinate with ARD to determine which parks need additional ozone monitoring and foliar injury surveys	ARD, LTEM
CULTURAL LANDSCAPE MANAGEMENT	IV, V	6-HIGH 6-MED 2-LOW	What natural resources need manipulation significant to cultural landscape?	Work with SERO-Cultural Resources Division to evaluate restoration efforts involving natural resources	SERO-Cultural Resources Division
FOREST INSECTS AND DISEASES	I, II, III	4-HIGH 8-MED	Are forest pests spreading into the park?	Work with USFS to determine which parks are currently covered by FHM or FIA plots	USFS
VISITOR USE IMPACTS	I, III, IV	4-HIGH 6-MED 2-LOW 2-UNK	Is trail use (horse, bike) impacting natural resources? Are rock climbing activities (CHCH, LIRI) impacting natural resources (esp. rare species)?	Conduct a literature review to determine which units in NPS have active trail/rock climbing monitoring, what research studies have been done, and what management actions have been taken.	Other NPS units with active trail/rock climbing monitoring
POACHING AND THEFT OF NATURAL RESOURCES	I,II, IV	4-HIGH 5-MED 2-LOW 3-UNK	What resources are at threat from poaching? Is poaching occurring?	Evaluate data from plant surveys and field plots to determine presence, location, and extent of populations known to be at risk	NatureServe, State Heritage Programs, LTEM

Current Monitoring Activities

Table 7 shows current monitoring activities based on input from park surveys Jan-May 2002. For a summary of past monitoring see Appendix B. For a summary specific to Air Resources, Appendix D and for Water Resources, Appendix E.

Table 7: Current Monitoring Activities

PARK	CURRENT MONITORING ACTIVITY	SOURCE OF MONITORING DATA
ABLI	Water Quality Monitoring Sinking Spring and Adjacent Landuse Study	Ky. Div. of Water Res. / Dept of Geology, WKU
CARL	Native and exotic plants	Assoc. for Bio-diversity Information / NPS I & M
CARL	Native plants and historic exotic plants (not represented in existing herbarium)	CARL volunteer(s)
CARL	Lichens, bryophytes, mosses, and liverworts	CARL volunteer
CARL	Exotic / Invasive plants	GRSM and CARL staff
CARL	Hazard Tree Annual Inspection	CARL staff
CARL	Exotic Aquatic Plants	GRSM and CARL staff
CHCH	T&E Species: Mountain Skullcap	Park staff
COWP	Ozone & Acid Rain	State Ozone/Acid Rain Monitor located in park
COWP	Hexastylus Naniflora	USCS-Dr. Gillian Newberry
COWP	Proposal To Do Lichen Monitoring	USCS-Dr. Gillian Newberry
CUGA	Wetland and amphib. 5-year agreement	Cooperator, Jim Petranka, UNC-A
CUGA	Water quality	In-house. Project funded. One more year.
GUCO	None	None
FODO	Identifying vascular plants.	Volunteer/Contract
FODO	Exotic Plants	Park staff and Joe Rogers GRSM
FODO	Plot Research	NatureServe
FODO	Fire Management	Robin Toole SER
FODO	Gypsy Moth	National Forest Service
KIMO	Water Quality mid-1990's	Park staff
KIMO	Fire Program	Park staff and GRSM Fire staff
LIRI	Water quality	Park Staff
LIRI	Green Pitcher Plant	Park Staff
LIRI	Fire effects	GRSM & NATR fire effects crews and myself
NISI	Vascular Plant Study	Mike Runyan. Lander Univ
SHIL	Water Quality	Biology Department, University of Memphis, Tennessee, under the direction of Dr. Jack Grubaugh. Besides documenting the usual indicators, the monitoring includes a significant aquatic species inventory.
SHIL	Endangered Bat Survey	Biology Department, University of Memphis, Tennessee, under the direction of Dr. Michael Kennedy. Research investigating the seasonal habitation of the park by both the gray and Indiana bat. The gray bat has been confirmed to inhabit the area from March through September in extremely low numbers. Populations of more common bat species are high and stable.
SHIL.	Fire Weather	Park Staff: The park possesses NPS fire records dating back to 1934, and additional War Department records indicating heavy use of fire to manage the landscape back to 1895. Archaeologists have uncovered evidence of prehistoric fire use associated with habitation of the Shiloh plateau by Woodland and later Mississippian populations.
STRI	Monitoring vegetation on earthworks. Funded for 2002.	Monitoring conducted by park staff on earthworks in 2000 and 2001 and 2002
STRI	Monitoring vegetation in cedar glades according to protocol completed in 1995. Funded for 2002.	Protocol written under agreement with The Nature Conservancy.
STRI	Monitoring vegetation in park for natives and exotics. Funded for 2002.	Preparing protocol April 2002.

Table 7: Current Monitoring Activities		
PARK	***CURRENT MONITORING ACTIVITY***	***SOURCE OF MONITORING DATA***
MACA	Water Quality Monitoring	Joe Meiman, Science and Resources Management
MACA	Monitoring aquatic macroinvertebrates in surface waters	Dr. Scott Grubbs, Dept. of Biology, Western Kentucky University
MACA	Mussel monitoring in the Green River	Dr. James Layzer, USGS/BRD Tennessee Cooperative Fisheries Unit
MACA	Fish monitoring in the Green River and its tributaries	Dr. Philip Lienesch, Dept. of Biology, Western Kentucky University
MACA	Aquatic fauna monitoring in subterranean streams	Dr. William Pearson, Biology Dept., University of Louisville
MACA	Allegheny woodrat monitoring	Steven Thomas, Science and Resources Management –LTEM
MACA	American chestnut monitoring	Science and Resources Management staff in cooperation with University of Tennessee
MACA	US EPA Source Drinking Water monitoring within Mammoth Cave National Park	Dr. Chris Groves, Western Kentucky University
MACA	Fire effects monitoring	GRSM Fire Effects Team; and Michele Webber, Science and Resources Management—LTEM
MACA	Forest health monitoring (FIA/FHM)	John Anderson, Kentucky Division of Forestry; and USFS
MACA	High intensity ginseng monitoring	Michele Webber, Science and Resources Management—LTEM
MACA	Muskrat and river otter monitoring	Dr. Joe Clark, University of Tennessee
MACA	Cave cricket monitoring	Kurt Helf, Science and Resources Management-LTEM
MACA	Surprising cave beetle monitoring	Kurt Helf, Science and Resources Management-LTEM
MACA	Bat monitoring	Kentucky Department of Fish and Wildlife Resources; USFWS; and Steven Thomas, Science and Resources Management-LTEM
MACA	Air quality monitoring (surface)	Bobby Carson and Johnathan Jernigan (ARD), Science and Resources Management
MACA	Cave atmospheric monitoring	Johnathan Jernigan, Science and Resources Management-LTEM
MACA	Vernal pool amphibian monitoring	Dr. Floyd Scott, Austin Peay State University
MACA	Breeding bird monitoring	Kentucky Department of Fish and Wildlife Resources; USGS/BBS; and Steven Thomas, Science and Resources Management-LTEM
Other regional monitoring activities include: EPA's "Environmental Indicators Initiative"and "Watershed Assessment"; TNC's "Ecoregional Conservation Planning"; USFS's "Forest Health Monitoring", "Forest Inventory Plots", and "Southern Forest Resource Assessment"; FWS's "North American Bird Conservation Initiative"; Southern Appalachian Man and the Biosphere; state heritage programs, state ginseng, fish, amphibian monitoring, and watershed watch programs; USGS "North American Amphibian Monitoring Program" and ARMI; and TVA's species monitoring program.		

Conceptual Models *(modified from workshop report prepared by Jack Ranney, Ecologist University of Tennessee)*

Conceptual ecological models for general aquatic and terrestrial ecosystems were developed with the Appalachian Highlands Network (AHN) at a workshop conducted by the University of Tennessee in July 2002. The workshop was attended by an interdisciplinary group of park resource managers, regional university scientists, and other federal land managers. The participants formed two groups, one for each model, and brainstormed on attributes, stressors, effects, and indicators for two days. The results of the workshop are discussed below. In addition to the general terrestrial and aquatic models developed at the July workshop, specific models for cave and karst ecosystems are being developed by Mammoth Cave's Long-term Ecological Monitoring program (Pers. Comm. Dr. Bob Woodman). The CPN plans to continue work with MACA-LTEM, AHN, and other cooperators in the development of meaningful ecosystem conceptual models.

The purposes of these models are to:

- *Conceptualize ecosystem functioning and structure (cumulative, holistic, multi-scale)*
- *Identify major stressors, attributes affected, impacts, and indicators at a broad level*
- *Help identify "vital signs" to detect ecological health changes*

The ultimate concern is to ***conserve and improve ecosystem health toward unimpaired conditions (or a particular historical point in time).*** This includes the spatial, demographic, and genetic dimensions of biodiversity and species composition. Explicitly linked to biodiversity are the maintenance/restoration and conservation of:

1. *Productivity and nutrient status for native ecosystems. This would also include the absence of environmental toxins, related bioaccumulation, and their effects on biota. Imbedded are functions of hydrologic cycles, biogeochemical cycling, energy flow, and numerous ecosystem services.*

2. *Habitat connectivity and arrangements at various geographic and time scales for the full complement of native species, approximating as closely as possible an unimpaired state – making possible the maintenance and movement of viable populations, and the colonization of suitable new/restored habitat. Disturbance patterns are a component.*

3. *Functioning relationships within native communities. These include the relationships of species and species groups (e.g., trophic structure, energy flow structure, and predator-prey dynamics).*

4. *Habitats for sensitive, declining, rare, threatened, and endangered species.*

Definitions of Conceptual Model Components

Drivers = major forces of change to ecosystems, both natural and anthropogenic
Stressors = results of major drivers that act on attributes of ecosystems to cause potentially adverse changes
Attributes = a selected subset of all potential biological elements of natural systems, which are representative of their overall ecological conditions. Attributes are selected to represent the overall health of the system, known or hypothesized effects of stressors, or elements that have important human values.
Impacts = changes that occur within ecosystems when stressors act on specific attributes
Indicators = measurable characteristics used to efficiently monitor ecosystem health and changes in stressors, attributes, or impacts

The terrestrial conceptual model is illustrated in Figure 1 with associated attributes and indicators illustrated in Figure 2. Figure 3 illustrates the aquatics conceptual model. Both models include a core of biotic and abiotic attributes. The similar drivers and stressors in these models pose some duel-use indicator possibilities for both aquatic and terrestrial systems. The common drivers and stressors are air pollution, water pollution/hydrology, land use change/adjacent land use/agriculture, natural biotic processes (e.g., succession), climate change, non-native invasive species, and various aspects of human activity in the parks.

Figure 1. Terrestrial ecological conceptual model. This model illustrates the drivers/stressors, responses, and some important relationships between them. (See Figure 2 for a list of potential indicators)

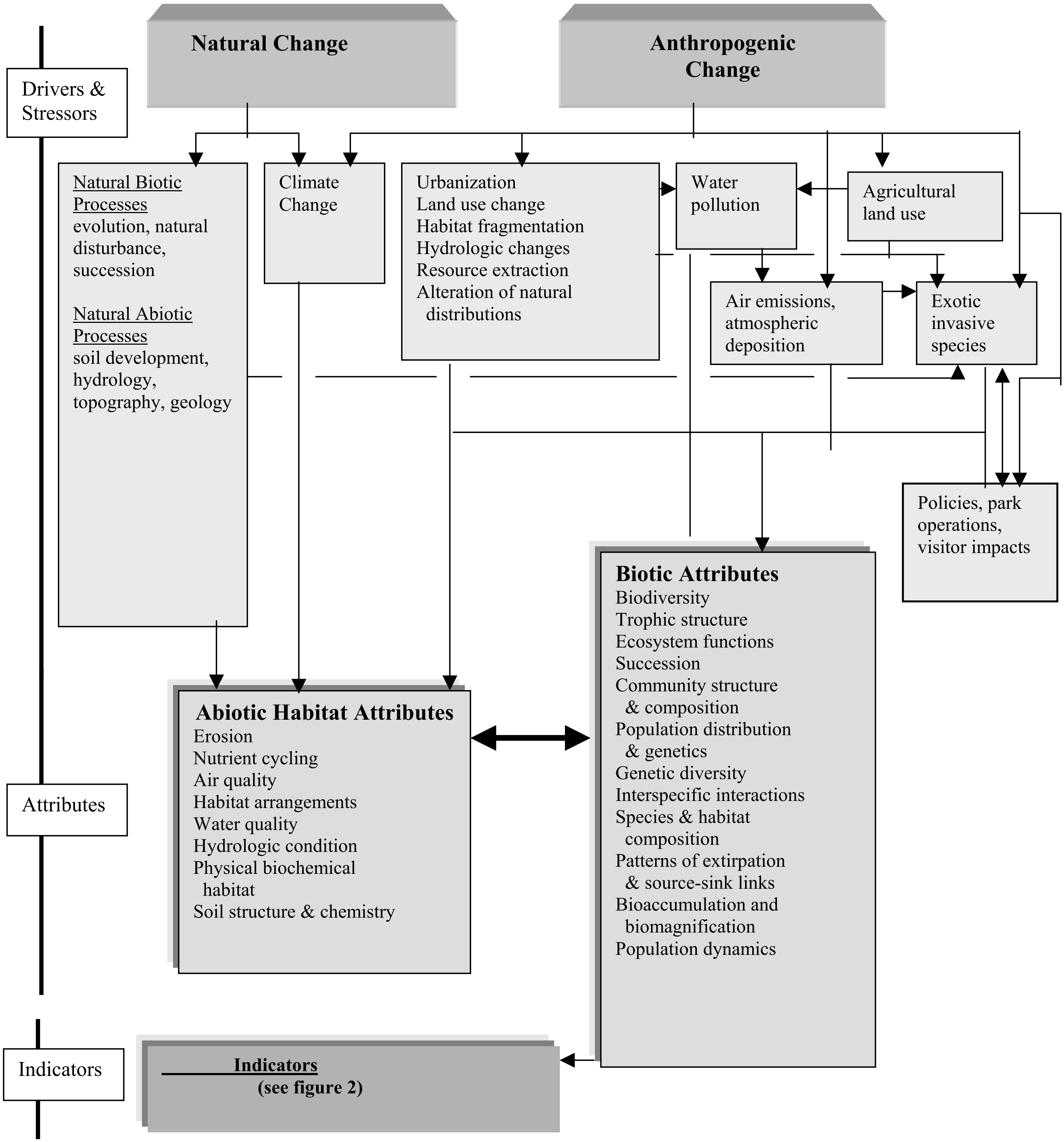


Figure 2. Potential indicators (at bottom of illustration) are based on relationships, processes, and desired conditions developed in the conceptual model (see figure 1). So many interrelationships (arrows between boxes) exist that both the attributes and indicators are lumped for simplification.

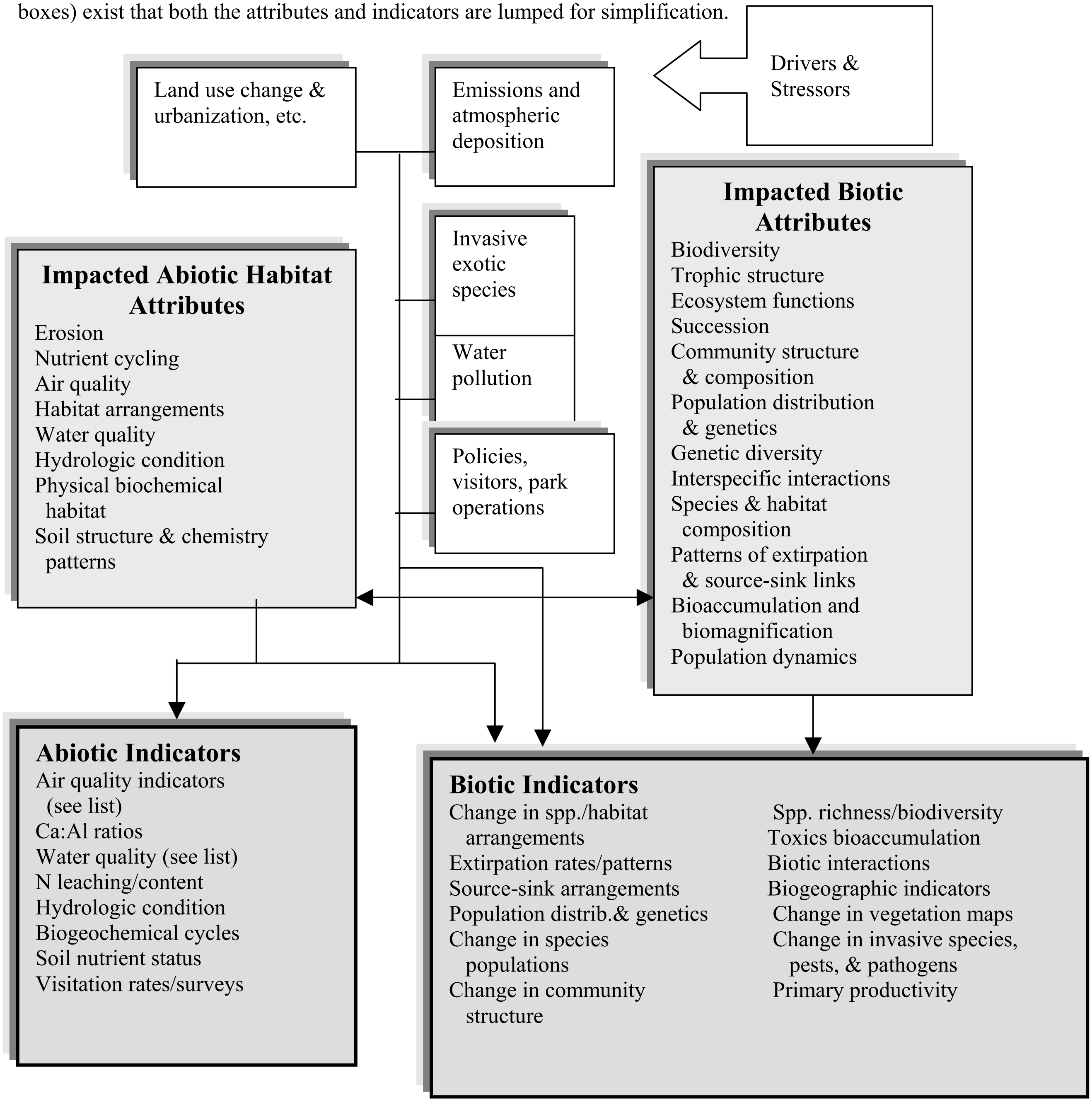
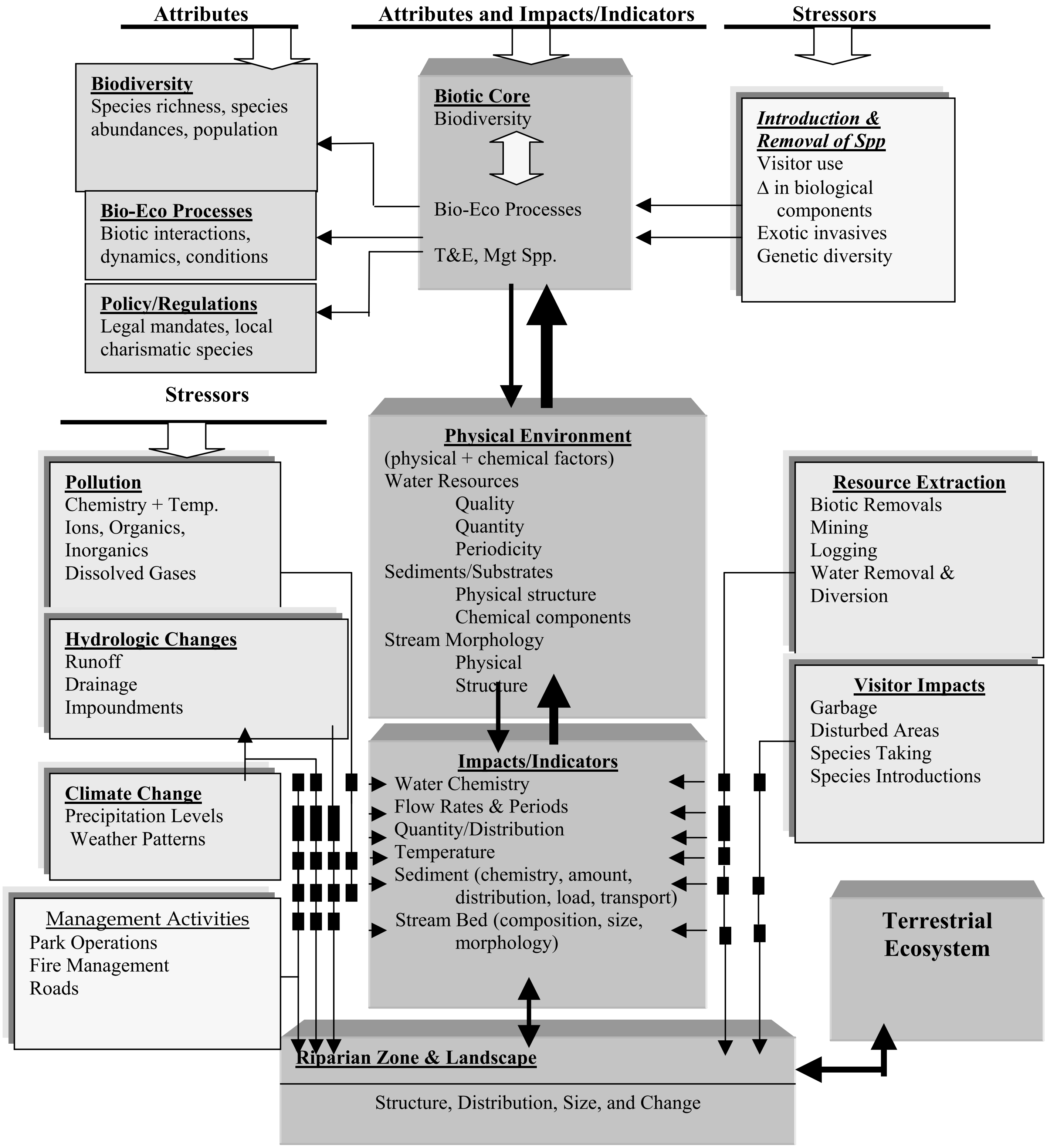


Figure 3. Aquatic Conceptual Ecological Model



Drivers and Ecological Stressors: Anthropogenic Drivers/Stressors

I. Air Quality Degradation

Air quality degradation involves acid deposition, ozone, toxins, visibility, radioisotopes, and nitrification. Of concern are both suspected and documented impacts to vegetation, water quality, exotic species invasions, nutrient cycling, and unique habitats/species highlighted.

Some of the highest air pollution exposures in the region are occurring in the park units of the networks, representing a major stressor to regional ecosystems (Chappelka, et al. 1999A; Eager, et al. 1996). Degraded air quality with respect to ozone events, acid deposition, heavy metal deposition, and haze (decreased visibility), stem from the combination of industrial pollution moving in from the Midwest, regional power generation from coal-fired plants, and local transportation-related emissions (Southern Appalachian Mountain Initiative report, August, 2002). Haze and high ozone levels are amplified by topography and summer air movement patterns in this region (Ibid). Pollutants of major concern include nitrogen compounds, sulfur oxides, mercury, organic compounds and ozone.

Ecological concerns in more vulnerable parks are high levels of air pollution damaging undetermined components of terrestrial biota (direct exposure) as well as indirectly stressing and altering ecosystem processes including soil chemistry and stream water chemistry (Herlihy, et al. 1996; Fenn, et al, 1998). The human health-based National Ambient Air Quality Standards appear insufficient to avoid suspected continued declines in ecological integrity of the region's forests and other native biota. Major indirect effects of air pollution on ecosystem processes depend on local buffering capacities and air quality conditions. Suspected or documented effects include (see Southern Appalachian Mountain Initiative Final Report, 2002):

- leaching of significant amounts of nitrogen and calcium from acid-sensitive soils and plant tissues (Eager, et al, 1996), thereby stressing or eliminating natural buffering capacity that resists acidification in some parks,
- acidification of streams and soils in acid-sensitivity locations/parks, causing losses of chemical components, especially nitrogen (Swank and Vose, 2001), important to productivity (Eager, et al, 1996),
- release of toxic elements, such as aluminum, into solution in soil and water – mostly for parks with acid-sensitive soils,
- suspected (undocumented) deposition of toxic heavy metals, including mercury, resulting in toxin bioconcentration in the tissues of species high on the food chain,
- stress in fauna (respiratory) and flora (leaf damage) due to exposure to high ozone levels (Chappelka et al, 1996A, 1999A),
- suspected (undocumented) damage to plant and animal tissues from possible higher UV-B exposure as a result of declines in stratospheric ozone concentrations, and
- Increasing carbon dioxide concentrations which alter functions of some plants (Owensby, et al, 1999) and global warming affecting aspects of climate and weather.

Acid deposition affects various ecosystems differently in the region depending upon their buffering capacity. The highest elevation systems and those areas underlain by non-limestone geology are the most vulnerable to change. Therefore, elevation and buffering capacities are important factors in risk assessment.

Increased concentrations of atmospheric carbon dioxide affect plant growth processes, favoring some species guilds (e.g., grasses, and some exotics) while discriminating against others. This could alter reproductive success, successional patterns, and the structure and distribution of ecological communities. (Owensby, et al, 1999; Ziska, et al, 1999)

Direct monitoring of various aspects of air quality is a primary need in this region. Since ecosystem responses vary, monitoring nutrient and chemical changes in soil and water, as well as direct damage to sensitive plants, is important. Long term monitoring of species composition and structure within various habitats and ecosystems, especially those most vulnerable, will provide early warning of major air quality-related changes.

II. Land Use/Demographic Change

Land use and demographic change impacts are from agriculture, farm land development, water pollution, water impoundments, hazardous material spills, habitat fragmentation, exotic species invasions, viewsheds, noise, and night lights. Concerns are highest for T&E species, water pollution, and identification of specific contaminants.

Population change inevitably results in land use change. For the parks, this includes pressures from adjacent lands, activities inside parks such as increased road and trail construction, other recreation-related development, and sometimes unsustainable recreational use. Although land use change can be expressed in various ways, the primary related ecological issues are habitat loss, habitat fragmentation, altered nutrient cycles, various types of pollution (air, water, noise, light), major hydrologic changes, siltation of streams, and increases in invasive and nuisance species associated with increasing urbanization (Southern Appalachian Assessment, 1996; Wear and Greis, 2001; Pearson, et al., 1999). Changes in hydrology (storm water diversion, impoundments, water withdrawals and other practices that lower streamflows and water tables) affect aquatic and terrestrial ecological resources (e.g., riparian habitats, wetlands, stream habitats).

Population increases and demographic shifts are associated with stressors such as the introduction of invasive exotic species, increases in emissions from automobiles and power plants, increased water pollution, expansion of rights-of-way, and clearing of forest and other native habitats for development (along with the associated increase in impermeable surfaces, and heat/light island effects). Rural and suburban sprawl include low-density development mingling with forest cover to create vastly altered landscape and habitat patterns. The dividing of existing native habitats into smaller and more isolated patches drastically affects native species dispersal patterns and reproductive success. All of these impacts are of particular concern because of rapid population expansion and second home development in this region.

Detecting effects specifically from land use change can be difficult. Monitoring biodiversity can be effective. Water quality and hydrology changes are good indicators. Monitoring for changes in landscape patterns from aerial photos, although accurate and fairly easy, requires inferences as to their ecological effects based on working ecological principles rather than clearly documented effects.

III. Invasive Exotic Species/Pathogens

Concern about ecological damage from exotic invasive species involves impacts to native vegetation, fauna, aquatic systems, and fire hazards. Especially among these are concerns for threatened and endangered species sustainability and loss of more common species. Invasive exotic species include terrestrial plants, aquatic biota, insects, diseases, and pathogens not native to the region that aggressively affect native species.

Every park in the region has experienced proliferation of invasive exotic species. Human population movement and interregional/international commerce have facilitated the spread of this destructive group of biota (Williamson, 1996). Invasive exotic plants and animals, diseases and other pathogens are affecting the composition and quality of habitat, and impacting native species populations, including threatened and endangered species (Ferguson and Bowman, 1994; Moony and Hobbs, 2000; Corn, et al, 1999; Miller, 1997). Evidence is mounting that species genetics and pollination dynamics are being altered as well (Johnny Randall, NC Botanical Garden, 2002, personal communication). Particularly damaging past, current, and potential future examples include gypsy moth, chestnut blight, dogwood anthracnose, balsam wooly adelgid, hemlock wooly adelgid, Asian longhorn beetle, sudden oak death, Dutch elm disease, beech bark-scale disease, European mountain ash sawfly, west Nile virus, zebra mussel, Eurasian water milfoil, purple loosestrife, butternut disease, cogongrass, Japanese stiltgrass, emerald ash borer, several species of bark beetles, princess tree, tree of heaven, invasive privet, multiflora rose, garlic mustard, and many more.

Exotic invasive species impose suspected stresses on natural systems that are not yet well defined but are becoming better understood (Leibhold, et al, 1995; Williamson, 1996, GAO, 2001)). Sometimes drastic measures necessary to control these invaders can also have unwanted impacts. Chemical or physical control efforts (USDA Forest Service, 1994) are often disturbances in themselves that can further alter habitat quality and quantity, at least over the short-term, requiring restoration efforts. Some exotic invasive species are so ubiquitous and hard to control (e.g., Japanese stiltgrass, gypsy moth, and chestnut blight) that they are now a permanent part of ecosystems generally with poorly defined ecological effects.

Monitoring should focus on early detection, defining existing distributions of species, and determining changes in distributions or rates of spread (changes at the margins of populations). Important concerns are the likely pathways of spread (vectors), invasions in sensitive ecological areas containing unusual or endangered species, and identifying and monitoring habitats or species particularly vulnerable to invasions/infections. Monitoring is also needed to identify the impacts of invasions that are diverse. Some variables to monitor are landscape or stream habitat patterns, species diversity, nutrient cycling, pollinator habits, and possible disturbance patterns. Early detection requires a combination of monitoring methods to be effective. These methods include permanent plots and frequent observation of vulnerable habitats and likely vectors.

IV. Hydrologic Changes

Hydrologic changes concern stream high and low flows in response to weather events, effects on aquatic life, and impacts to recreation and aesthetics. Adjacent land use, climate change, and impoundments are major drivers.

The primary concerns include stream channelization, altered storm water discharge, effects of impoundments, wells, low flow during drought periods, oil extraction spills/impacts, and stream water withdrawals. The terrestrial concern with these changes is related to water table drawdown (loss of small wetland habitats), riparian habitat loss, and stream bank scouring that can lead to erosion/sedimentation and associated habitat degradation, as well as invasion by exotic plants.

The aquatic concern is with stream discharge (flow) dynamics and effects of hydrology on stream physical conditions (water quality and stream substrate conditions). Stream discharge dynamics continue to be altered by impoundments, water withdrawal, expansion of impermeable surfaces in watersheds, climate change, loss of riparian buffers, and changes in runoff characteristics under various vegetation conditions. These lead to concerns for extreme events in low stream flow, flooding dynamics, sediment movement and channel scouring, flow responses (spikes) to storm events, and altered stream water temperature profiles (Harding, et al., 1998).

The primary indicators to monitor are stream flow, especially during unusual weather events, water table changes, stream channel characteristics, and changes in watershed land use. These watershed characteristics extend outside park boundaries to include number and type of impoundments, percent impermeable surface, and percent cleared forest.

V. Water Quality

Water quality concerns are with off-site pollution, inappropriate visitor use, atmospheric deposition (stream acidification), water pollution effects on use of water resources, and loss of aquatic biota.

Concerns over changes in water quality are so imbedded in, and important to, the other areas as to be repetitive here. One example is acid deposition effects on aquatic resources (Herlihy, et al, 1996) Rather than repeat them, the primary monitoring concerns are identified. These focus on chemistry and biodiversity (Harding, et al, 1998) and include water chemistry, temperature, presence of ions and organic compounds, inorganic pollutants, and dissolved gases. The two primary ecological concerns with water quality are (1) as an indicator of terrestrial ecosystem functions (nutrient cycling, elemental content, and acidity) and (2) habitat and substrate for aquatic biota (Rosenberg and Resh, 1993).

The various key indicators are dissolved oxygen, temperature, pH, buffering capacity, sediment load/turbidity (Reidel and Vose, 2002), coliform count, concentration of nitrogen compounds, species abundance/diversity (e.g., algae and plants, bacteria, zooplankton, macroinvertegrates, fish, amphibians, reptiles, and water birds) (Grossman and Ratajezak, 1998), detritus composition, and presence of key pollutants to T&E species. Well documented USGS core parameters along with macronutrients are potential indicators as are riparian birds, macroinvertebrates, fish, and amphibians.

VI. Agricultural Land Use

Adjoining agricultural land use stressors concern agrichemicals, water use, and changes in crop management that would affect water quality, habitat fragmentation, invasive species dynamics, and possibly genetics of native biota.

Agricultural practices are believed to be changing (e.g., water management, pesticide use, tilling practices, role of farm ponds, and crop rotations) and there may be a transition to intensive production systems in some areas.

The primary concerns are erosion (movement/loss of topsoil), changes in soil structure that would affect hydrology, chemical and nutrient runoff, and productivity (e.g., changes from pasture to row crops). Changes in the use/movement of fertilizers, pesticides, and dust as well as use of genetically modified crops that might affect pollinators and other insects are of concern. Possible hydrologic alterations from changes in storm runoff and irrigation practices are significant concerns. There may be recent trends toward larger tracts in single crops and changing land use patterns around parks. This affects the creation or destruction of habitat corridors for both native and pest species and factors related to pollinators and genetics. Future agricultural trends may include further concentration of livestock into intensive production systems (e.g., chickens and hogs) that involve mass regional movement of nutrients and their disposal/accumulation in soils through long term fertilizer use and waste disposal (e.g., nitrogen in eastern North Carolina). These have strong implications for future productivity, land use patterns, and water quality/quantity issues that relate back to terrestrial ecosystems.

Detection of these changes may best involve the monitoring of stream hydrology, water quality (i.e., content of macronutrients, pesticides, and turbidity), landscape patterns, and changes in bird and pollinator populations.

VII. Resource Extraction

Resource extraction impacts in/near some parks concern mining, nearby timber harvesting, and withdrawal of limited water resources. The major concerns are contaminated mine drainage, erosion, siltation, and impacts from construction and access. Park aquatic habitats are most directly affected but long term impacts to park terrestrial biota are of concern as

Extracting minerals (coal, oil, gas) can increase sedimentation or drive the concentration of chemicals to toxic levels (e.g., brine, heavy metals, hydrocarbons). Extracting water, river rock, sand and gravel can alter habitat by altering flow volume and patterns, reducing bank stability and changing sediment deposition patterns. Reductions in flow volume can impact water quality by concentrating potentially toxic substances, reducing light penetration, and increasing water temperature. Water table changes may also occur as a result of mining and well drilling which can affect water table-dependent habitats. Timber harvesting, poaching, and rare plant collecting within and adjacent to parks are problems for park biota. Devastating spills of hazardous substances are of concern in several park units.

Potential indicators to monitor are toxins in streams, bioaccumulation of toxins in tissues, siltation/sediment patterns in streams, numbers or acreage of extractive actions, water table levels, and stream flow patterns.

VIII. Inappropriate Recreational /Resource Use

Inappropriate visitor use of natural resources is affecting cave environments, trail corridors, rock outcrops of various types, stream and lake environments, air quality, campsite areas, and dispersal of invasive species.

Demographic changes (Southern Appalachian Assessment, 1996) can dramatically increase park visitation and recreational use, sometimes to unsustainable levels. Park traffic emissions, noise, trampling of sensitive habitats, poaching, cliff and cave use, horseback riding, ATV use, hiking, swimming, boating, and recreational development, to name a few, can have direct and indirect impacts on species reproduction and survival, as well as habitat availability, fragmentation, and quality.

Variables to monitor might include visitation rates, loss of species, introductions of exotic invasive species, soil structure, air quality, noise levels, and water coliform content.

IX. Climate change

Concern for high-alpine relic communities and high-elevation T&E species are important issues that may be best evaluated by monitoring cold-adapted species and communities. Other issues relate to changes in weather events, growing season changes, and other aspects of natural disturbance regimes that would alter natural communities and facilitate general change in

Increasing carbon dioxide concentrations in the atmosphere may be effecting climate change (Burkett, et al, 2001; Climate Change Impacts on the United States, 2000), which will result in more frequent or more severe storm events (altering natural disturbance regimes), altered annual rainfall (affecting wetlands, stream, and forest/community species composition and structure), and significant changes in the timing of last spring frost and first fall frost (important reproductive implications for plants, birds, amphibians, and insects, among others). Such changes could drastically alter the structure and distribution of ecological communities, especially in areas with high biodiversity and endemism (Peine (ed.), 1998; Melillo, et al., 2001; Burkett, et al., 2001).

Weather is so variable from year to year that detection of significant climate changes is difficult. Recommended indicators to monitor (ibid.) are changes in habitat margins (habitat distribution and pattern), first and last frost dates, soil biota changes, stream flow patterns, growing degree-days, precipitation events, tree rings, and atmospheric carbon dioxide content.

<u>Additional Management Issues To Consider</u>

- Fire – for management of native communities as well as fuel loads
- Native Species Populations – concerning major tree species, often collected herbs, many aquatic, high-elevation invertebrates, cliff, and cave species, bats, bald eagles, fresh water mussels, cave shrimp, and state listed species
- Geological Resources – especially cave and cliff (rock outcrop) formations
- Re-introduction of Extirpated Species – which species, likely success, effects to other native species, and associated concerns about the genetics of individual species re-introduced.
- Threatened and Endangered (T&E) Species – many questions (and legal mandates) some of which concern augmentation of populations, determination of habitat preferences, modification

of natural and anthropogenic disturbance regimes to accommodate T&E species, response to FERC permits and other adjacent land use changes, level of control over limiting factors/threats.

- Poaching and Theft of Natural Resources – especially which resources are at threat and distribution of those resources.
- Cultural Landscape Management – an area of major concern addressing natural resource components of battlefields, historic homesites, archaeological sites, caves, and water bodies. The issues address the condition of the natural resource of significance to a park's cultural landscape. Included in this is rehabilitation of disturbed areas with issues concerning exotic pests, natural habitats, and relationships to cultural landscapes.

Some indicators that might be useful to monitor based on these issues are:

- *For fire:* fire fuel load, number and intensity of fires, species composition after fires, and extent of fire-maintained communities.
- *For native species populations:* specific species population levels including population structure, breeding pairs, and reproductive success.
- *For geologic resources:* damage and loss rates of specific features.
- *For species re-introductions:* occupation rate of suitable habitats, population dynamics, genetic diversity, and specific interspecies interactions.
- *For threatened and endangered species:* see "species re-introductions." Include also the listing of T&E species and loss of species T&E from known locations.
- *For poaching and theft:* quantity of poached species confiscated and population structure of likely poached species
- *For cultural landscape management:* species inventories, habitat (landscape) patterns, exotic invasive species, soil structure, water quality, and parameters related to the physical structure of terrestrial vegetation and stream morphology.

Natural Change:

I. Natural Disturbance

Natural disturbance regimes, which are crucial to ecosystem integrity and function, include fire, storms, landslides, floods, drought, and native pest outbreaks. The frequency, intensity, and distribution of these are constantly being altered by a long list of human activities, some of which are described in the previous section. Because of past alterations of native ecosystems in this region, including the removal of dominant trees such as the American chestnut and many decades of fire-suppression in fire-dependent ecosystems, it is difficult now to establish a baseline for natural disturbance regimes. Anthropogenic change, as well as potential restoration efforts, will undoubtedly continue to alter this baseline. Restoration of American chestnut populations, as an example of one of many restoration possibilities, would impose an extirpated species into an "adjusted ecosystem" which is unlikely to return to its original state given the breadth of alterations by many other factors. In the wake of recent catastrophic wildfires, there is now a movement away from the total fire suppression emphasis of the past toward the opposite extreme, resulting in prescribed burning of some inappropriate habitats, in addition to the necessary burning of fire-dependent systems.

Monitoring of any of the regional ecosystems will need to accurately recognize the role of natural disturbance regimes and find ways to detect and diagnose the causes of subtle, as well as, large changes within the ecosystems that are dependent upon these disturbances. These will entail the characterization of the frequency and severity of naturally occurring fires, landslides, ice storms, droughts, pest outbreaks, spikes in animal populations (e.g., deer, bears), torrential downpours/floods, and other episodic events. Landscape pattern analyses, geologic pollen records, tree rings, sediment analyses, and soil patterns may help define these natural disturbance regimes.

II. Climate Change

Whether natural or anthropogenically influenced, climate change is a major driver of ecosystem change because it affects all the “lower elements” of the model, including microclimate, soil chemistry, and geographic distribution of species. Interacting with the abiotic factors of soil, topography, hydrology, and geology, climate change defines the range, abundance and spatial distribution of habitats and species.

The primary concern is to establish a climate base line with defined confidence limits for the region. It has been difficult to translate global climate change models into local or regional changes in weather and climate. Projecting natural changes and/or separating them from anthropogenic changes is even more difficult.

Potential Attributes, Ways They are Monitored, and Relationship to Stressors

Abiotic Attributes:

I. Soil Quality

Soil quality is a particularly important attribute. Soil structure, percolation, carbon content (both elemental and organic), profile condition (especially A and B horizons), litter layer condition, soil surface stability, and mineral soil exposure are all valuable measures of soil quality. Of these, the greatest response may be detected in litter layer conditions and soil carbon content. These attributes integrate a large number of factors and represent a sensitive early warning of change. Soil carbon can be related to productivity changes, soil chemistry, and community changes which in turn relate to a wide number of the stressors identified in Figure 1.

Erosion and sedimentation are directly indicative of soil disturbance and provide a good indicator of the rate or extent of land use change. Monitoring sediment increases and turbidity in streams, as well as the extent of exposed soils from aerial photographs are all good measures. They may also be indicative of habitat fragmentation as well as potential food losses to terrestrial species feeding on stream and riparian biota.

Soil testing laboratories can measure percolation rates, bulk density, and particle composition (e.g., loams, clays, etc.). They can also classify samples into soil types and infer erosiveness:slope relationships.

II. Soil Chemistry

Soil chemistry attributes of most concern for ecosystem health are carbon/organic matter content, nitrogen leaching (leachate quality from soil profiles), macronutrient content, chlorinated pesticide content, heavy metal content, and aspects of biogeochemical cycling including Ca:Al ratios, soil pH, and cation exchange capacity.

Soil chemistry can be evaluated through instrumentation installed in the ground to collect water at various depths as it passes through the soil profile. Soil samples can also be taken and analyzed in soil laboratories. A few very portable instruments can be used to measure soil conductivity, moisture content, and pH. There are also simple field tests to measure soil percolation (more of a physical attribute).

III. Air Physical and Chemical Qualities

The primary physical atmospheric qualities of concern are UV-B radiation, temperature, movement, and humidity. Ultraviolet radiation in the “B” frequency is noted for being particularly harmful to some organisms during reproductive stages, and to organisms with sensitive cutaneous layers (as with humans). Direct measurement of UV-B is possible (http://www.forestry.umt.edu/research/MFCES/programs/primenet/ultraviolet_radiation_monitoring.htm#info and http://uvb.nrel.colostate.edu/uvb/uvb_program_overview.htm). There is also an inverse relationship between UV-B radiation levels and stratospheric ozone concentrations (Melillo, et al., 2001).

Temperature change, although highly variable, is simple to measure, and one of the direct indications of climate change (global warming) when analyzed in the context of large data sets. More locally, the influence of heat islands from neighboring cities and towns can be detected. Other important information that can be extracted from temperature measurement is the calculation of growing-degree days that are important in assessing changes in primary productivity.

The combination of particulate concentration and humidity affects visibility impairment, and visibility impairment adversely affects visitor enjoyment of the parks. Particulate concentration is determined by various chemical attributes with visibility impairment a calculated value (deciview). Summer stagnant high pressure systems contribute to high ozone concentrations, too (Southern Appalachian Mountain Initiative Final Report, 2002). Visibility impairment can be monitored photographically with 35mm digital or video cameras. Special filters can be used to monitor particulates in the air.

Atmospheric chemical attributes include ozone, sulfur oxides, nitrogen oxides, acidity of atmospheric deposition, and carbon dioxide. Ozone affects the respiratory tracts of animals and directly injures sensitive plants. Ozone monitoring can be conducted by direct ambient measurement instruments that include permanently-fixed and portable, e.g., 2B Tech, continuous or "active" monitors and passive monitors, e.g., Ogawa) or through monitoring damage to selected indicator plants. Both of these measurements are important in understanding the toxic effects of ozone concentrations and exposure patterns. Monitoring of animals for respiratory effects is probably not possible except in the lab.

Acid deposition can be measured directly (wet and dry and fog/cloud deposition). Sulfur and nitrogen compounds can be collected with instrumentation to determine both dry and wet atmospheric deposition. Precipitation acidity is another direct measure. Other less direct indicators are acidity and acid neutralizing capacities of streams, acidity increases in soil chemistry, Ca:Al ratios in stream water and soil leachate, atmospheric ammonium, declines in soil cations, nitrogen concentration in streams, water conductivity changes, and reduced calcium concentration in leaves.

Carbon dioxide is well known for its effects on altering plant growth (respiration and photosynthate allocation) as well as being the major contributor to the greenhouse effect (Greenland and Swift, 1990; Melillo, et al., 2001). Carbon dioxide can be measured indirectly by effects to plants (e.g., leaf stomata aperture diameter and leaf-atmosphere gas exchange rates) or directly, and much more easily, by direct atmospheric measurement.

IV. Water Quality and Hydrologic Condition

The physical attributes of water quality are temperature, suspended solids, and speed of discharge. Storm discharge rates, when tied to the intensity of storms, can indicate upstream watershed conditions such as impermeable surface extent and other factors associated with urbanization. These, in turn, might indicate habitat loss and habitat fragmentation.

When hydrologic conditions change in a watershed due to development, the seasonal dynamics of water temperature will change during storm events. Even ambient stream flow temperatures will change due to development-related changes upstream.

Of particular concern in the region is the effect of impoundments on water temperatures and stream biota. These and the other factors listed above influence stream productivity and food availability for some terrestrial species.

USGS standard water sampling methods are recommended. Water temperature can be easily monitored directly with a thermometer. Suspended solids and turbidity can be measured in several ways including small samples taken to a lab or on-site observations of patterned discs to note the depth at which the patterns are no longer discernable. Speed of discharge is a little more complicated since water flow rates vary across the profile of a channel. Consistent sampling points can reduce some of this complexity.

V. Pollution and Water Chemistry

Water chemistry (pH, acid neutralizing capacity, conductivity, nitrogen content, coliform content, organic chemical content) is an extremely important indicator of the health of terrestrial ecosystems. Many of the chemical changes are described in the Aquatic Model and related to specific ecosystem attributes. Reductions in pH and acid neutralizing capacity are closely linked to atmospheric acid deposition and/or acid drainage from mines and can stress plant growth and soil productivity. Where upstream watersheds are natural areas in parks, increased nitrogen content in water can be an indication that upstream ecosystems are not retaining nutrients and are declining in productivity, or that there is excessive atmospheric nitrogen input. Where streams originate outside park boundaries, such water quality changes could be a response to agricultural fertilizer use. Organic chemical content may indicate land use changes upstream, especially mining or industrial activity. These organics affect freshwater mussels and other aquatic organisms directly, and are also indicative of overall watershed problems affecting riparian and terrestrial biota. Increased acidity in aquatic systems can raise concentrations of dissolved aluminum, which is toxic to native biota, both aquatic and terrestrial. Whenever evaluating water acidity, it is important to ascertain acid neutralizing capacity to understand the dynamics of the system. Acidity and acid neutralizing capacity are therefore good candidate indicators. Similarly, measurement of coliform content can be indicative of human and animal waste problems upstream and can relate to storm water discharge from urbanizing landscapes.

VI. Landscape Pattern and Its Change

Care must be taken in defining physical connectivity since connectivity is a combination of actual physical conditions/arrangements of habitats <u>and</u> the ability of different species to use habitats and to cross barriers (Forman and Godron, 1986). A single landscape pattern can be interpreted many different ways depending on the species of interest.

Some of the indicators of significant changes in landscape pattern include linear extent of edge, average size of habitat tracts, connectivity and width of riparian corridors, distribution of sizes of habitat tracts, percent forested land, edge-to-area ratios for habitats of concern, and average distance between habitats of various types (Turner and Gardner (editors), 1990). These measurements are best made simultaneously and can be obtained from maps and aerial photographs using landscape analysis software available in the public domain (McGarigal and Marks 1995; McGarigal, et al. (In prep)).

Results from landscape pattern analyses can help characterize changes in patterns over time, scale, arrangements of valuable habitats for selected species, and ways landscapes might be modified to reduce negative effects or increase positive effects on species of concern (Costanza and Maxwell, 1994; Skovlin, et al., 2001). Results have been used, for example, to determine how to modify landscape patterns to reduce invasive plant problems (e.g., reduce fence rows and edges) or where to improve connectivity of riparian corridors.

VII. Biogeochemical Cycling

Measures of biogeochemical cycling, although complex, can help define the mass balance of elements within terrestrial and aquatic systems including P, K, Ca, Mg, N, C, as well as micronutrients and heavy metals. Measurements are used to determine if a system is gaining, losing, or maintaining stable concentrations of various elements. Systems maintaining constant states may be considered in balance, at least for the elements evaluated. Significant loss or gain of elements is a good indicator of change in the system such as acidification or large accumulations or losses of biomass. Nitrogen has often been used as the key indicator of biotic changes (Eager, et al., 1996; Johnson, et al., 1998). Acidification of soils, leachates, and streams and the relative concentrations of calcium and aluminum are key measures of major adverse changes.

Biotic Attributes:

Biotic attributes generally fall into the categories of biodiversity, genetics, population structure and distribution, natural invasion/dispersal/competition processes, bioaccumulation processes, inter-specific relationships, other ecosystem functions and indications of habitat conditions and ecosystem integrity. In many cases these are simply presented as important broad categories with no further descriptive refinement.

I. Soil Biota

Soil macrofauna, macroinvertebrates and microbiota can be excellent integrated indicators of climate change (Rillig, et al., 1999; Soil Biota and Climate Change, 1998), land use fragmentation, soil chemistry and nutrient cycling (Hendrix, et al. 1998), physical qualities, and recovery from past disturbances. Some of the biota respond strongly to minor changes in soil temperature regimes, chemistry, moisture conditions, soil physical structure, and organic matter qualities/input. Soil biota composition, diversity, biomass, and population structure (e.g., worms per Bouche, 1977) should be considered for terrestrial ecological health vital signs. The greatest limitation is the limited knowledge that exists for calibrating soil biota characteristics with ecological health. This is an important area for research for natural area ecological health monitoring.

Methods usually involve collecting soil samples and separating macro-organisms from soil and dead organic material. Often organisms are separated by genus or family rather than species except for some well-known organisms. Micro-organism separation and identification require quite different methods.

II. Biodiversity

Significant change in native biodiversity is a key early warning of ecosystem distress. Biodiversity measures can monitor links between terrestrial and aquatic systems (Bardgett, et al., 2001), between above- and below-ground systems (Hooper, et al., 2000), or the health of natural life support processes (Naeem, et al., 1999). The region encompassing these parks has more species of snails, freshwater mussels, salamanders, and trees, for example, than any other temperate region on Earth (Stein, 2000). Increasing biodiversity is believed by many to increase ecosystem functions (Martinale, et al, 2002) but there are those who find such relationships between biodiversity and ecosystem functions such as productivity hard to clearly identify (Huston, 2000). There are many ways of measuring biodiversity. It can include an inventory of the total number of species, separating natives from exotics. Species can be grouped into plants or animals or other taxonomic groupings, or into a particular guild, or some other functional aggregation. The different number of genera or families of organisms present, rather than the number of individual species in these groups might for example, measure biodiversity. Biodiversity is also a measure of the evenness in representation of different species or groups in an area. The outright loss of particular species may be a good indicator of some ecological change but it could also indicate a specific temporary problem specific only to that species.

III. Genetic Diversity

In rare species that exist in metapopulations, genetic analysis can explain the species' historic distribution, identify detrimentally isolated sub-populations, and generally define the dynamics of species movement and survival. Isolated populations may interact (exchange genes) at widely varying frequencies, but through genetic analysis, even infrequent gene exchange events have been shown to be very important to species survival. As landscape patterns change and populations are reduced or extirpated, the overall long-term viability of these species may be affected through reproductive isolation and associated inbreeding depression or other adverse genetic effects. Genetic content is an important consideration when re-introducing species into areas where they have been extirpated or where habitat seems suitable but the species is not present. Monitoring change in genetic diversity is important as an early warning of ecological stressors. Genetic markers, DNA sequencing, phenotypic studies, and other methods of distinguishing genetic variations are the monitoring variables of concern.

Even with the common species of the region, amazingly little is known about their genetic diversity. Studies on the saw whet owl, for example (personal communication, David Withers, TN Dept. Env. & Conserv., 2002) have indicated that maximum diversity exists in the region. Common species such as black locust (Chang, et al., 1998) are just being evaluated while many other species intraspecific genetic diversity is unknown. Monitoring changes in major species genetic diversity could provide valuable indicators of ecological health in the region.

IV. Population Dynamics

Populations of species can sometimes exhibit wide natural fluctuations. Because of this, monitoring of population numbers, without understanding the range of natural fluctuation, will not be diagnostic. However, human-caused stressors are often significant enough to push population fluctuations outside normal ranges or to alter normal responses to naturally occurring feedback and control mechanisms. Since populations can be described in terms of birth, growth, reproduction, dispersal, and death (with numerous variables under each of these categories), they can be analyzed for the most critical aspects of their life cycles with respect to human-caused stressors. Monitoring population dynamics can evolve from early warning to diagnostic. The classic example is the detection of a decline in bald eagles (early warning) that led to studies showing reproduction constraints (along with poaching) as a problem. This led to the identification of eggshell frailty and consequently to tissue studies showing DDT-related problems.

V. Threatened and Endangered Species

Threatened and endangered species are an aspect of biodiversity important to the region, and parks are mandated to monitor their condition and implement conservation activities to further their recovery. The high endemism generated by the topographic isolation of species, along with pressures from the rapidly expanding human population, has resulted in a large inventory of T&E species. Evaluations of species such as fresh water mussels in the parks (Biggins, et al., 1997) have helped document the species, some of the circumstances, natural and man-made, leading to their condition, and practices necessary for their conservation and sustainability. The list of T&E species in the region is quite long as identified by the US Fish and Wildlife Service for National Parks. The Great Smoky Mountains National Park is among the top 10 parks for number of T&E species. Cave fauna (e.g., Mammoth Cave), a major component in the region, are emerging as vulnerable species to environmental stressors. Other T&E species are coming under stress from invasive species impacts, land use change, and suspected chronic exposure to degraded air quality. As a mandated responsibility for the National Park Service to conserve T&E species, the issue of monitoring T&E species is high priority. However, their suitability for indicators of ecological health is less clear. Groups of species may provide some indicator value as potentially with recent noted declines in amphibian populations (Blaustein and Wake, 1995).

Monitoring the condition of T&E species and how this number changes through time may be an indicator of environmental stress. Individual T&E species can be so affected by specific problems resulting from severe population depletion, specific diseases, or other factors, that one species may not represent a good indicator of overall ecosystem health. However, analysis of the threats to T&E species in a specific area can often illustrate patterns of ecosystem dysfunction, such as abnormal fire suppression.

VI. Trophic Structure and Function (including Productivity)

Trophic structure and function refers to the relationships that exist between primary producers (green plants), primary consumers (insects and animals, for example, that feed directly on plants), secondary and tertiary consumers (further up the food chain), and decomposers/detritus feeders. If there is a loss or change in any of these different “trophic levels” it may be a response to an environmental stressor or to processes of natural succession. One attribute to monitor is primary productivity (measured as a photosynthetic rate per unit area). Net primary productivity is another indicator, usually measured as inventories of vegetation biomass per unit area. Trophic levels relate to one another in the way one group feeds on another. In essence it is a flow of energy and nutrients through the ecosystem. Ecosystem energy flow is difficult to monitor so other monitoring methods are recommended. Monitoring representative trophic groups for standing biomass is easier. Also, predator-prey relationships offer easier monitoring opportunities as long as more than one predator-prey relationship is considered. An example of this might be to monitor the relationship between foliage biomass and leaf-feeding insect biomass over several plots at specified intervals, perhaps organized by habitat type or vegetation type.

VII. Interspecific Interactions

The interaction between two or more species changes and fluctuates naturally due to natural stressors. Interactions may also change in response to anthropogenic stressors. Relationships of, for example, turkey reproduction/populations to oak mast production, bear reproduction success to blueberry production, bear-human interactions, and brook trout distribution to rainbow trout distribution are sample types of interspecific interactions. The relationship may be as simple as browsed vegetation and deer populations with the variables being numbers of selected plants, numbers of deer, and clarity of definition of a browse line.

VIII. Ecological Communities

Community attributes can be a sensitive indicator of change. Some changes occur without anthropogenic stressors, such as natural succession and responses to natural disturbance regimes such as fire, drought, and severe storms. They also respond to anthropogenic stressors listed in figures 1 and 3. A question that has challenged ecologists for decades has been to understand how different ecological communities resist stressors, and why some are more resilient than others at recovering from adverse impacts.

Ecological communities can be difficult to define. In the Cumberland-Piedmont and Appalachian Highlands region, communities may be better described as frequently encountered associations of species that are often in transition with other associations almost to the point of providing a continuum of species distributions dependent on both biotic and abiotic environments. These continuums occur both across the landscape and through time. Communities are frequently defined by dominant tree species (e.g., oak-hickory, oak-pine, cove hardwood, cedar glade). More detailed community classification systems use extensive species lists, in part because this region is much more diverse than many others. Within this long list, particular species are often found that only occur in very specific habitat conditions, thus representing good indicators of the community's functional integrity.

Community change in response to stressors may be measured by changes in the relative occurrence/abundance of particular species, the presence of indicator species, biodiversity, the structure of vegetation layers, the extent of dominance by normally dominant species, microclimate, and understory plant composition.

IX. Succession

Succession refers to the process of continual turnover in natural communities through time. There are several factors involved in this process. As vegetation grows it changes its own environment. For terrestrial systems, bare soil becomes covered with plants that help cool the soil, build up organic matter above and below ground, and conserve soil moisture. This creates a changed habitat that favors different plants and animals. These, in turn, create conditions favorable to still other species. This process is dependent on the species that can invade an area over time as well as the physical conditions of soil, geology, topography, and precipitation. On top of all this is a regime of natural disturbances that occur at some given intensity and frequency, and in some combination with each other. Fires, droughts, severe storms, landslides, and floods are some of these disturbances. These tend to reset successional processes, or hold them in check at some level. Similarly, human-caused environmental stressors may alter community composition and structure, and establish a new set of baseline conditions upon which successional processes operate anew. Similar processes exist for wetlands, water bodies, and streams.

Monitoring succession to detect changes in ecological stressors is possible but somewhat problematic. It involves an evaluation of the sequence of species that enter, or do not enter, a site over some given time period, usually measured in decades. These include both expected and unexpected species. It is also possible to evaluate a landscape mosaic or aquatic habitat mosaic to determine the relative coverage of various community types. The difficulty is that it is challenging to separate natural and human-caused stresses as the cause of change.

X. Bioaccumulation

Bioaccumulation is the process of dispersed, low concentration toxic substances being ingested and passed up the food chain to become more and more concentrated in higher trophic levels, until they eventually become lethal. This can occur in whole organisms or in particular tissues. Noted examples are DDT, PCBs, dioxins, mercury, and other heavy metals. Specific stressors of concern in this region are atmospheric deposition of mercury, organic contaminants from fossil fuel extraction, pesticides, and contaminants in storm water runoff from parking lots and roads. Atmospheric deposition of mercury (and some other isotopes) is occurring everywhere. The other stressors of concern usually enter the ecosystems through spills or leakage into streams, from which they proceed into terrestrial food chains.

Monitoring of selected tissues in certain species for mercury (Custer, 2000) is a well-documented procedure under US EPA protocols. Of prime concern for many of the other contaminants is accumulation in freshwater mussels, in species that feed on aquatic insects and plants, and in carnivorous species that feed on the aquatic-feeding species. Tissue concentrations of most of these contaminants have been measured well beyond natural background levels and are easily linked to anthropogenic causes, although specific origins of the contaminants may be difficult to locate.

Conceptual Model Discussion

These general models illustrate that the drivers and stressors for both systems are essentially the same: air pollution, water quality and quantity, adjacent land use and disturbance, exotic invasive species, climate change, and inappropriate visitor use in parks. Many ecological and physical environmental attributes to monitor for ecological health in aquatic systems apply to terrestrial systems and vice versa. This is because water conditions are an integrator of ecological conditions and the stressors/drivers that act upon them.

The models imply that general biodiversity and ecological processes/structures are essential components that indicate ecological health. The models also imply that monitoring the condition of individual species in such a biologically diverse ecosystem may not be appropriate for monitoring ecosystem health, although monitoring of guilds or groups of species may be. Direct monitoring of some stressors is important but linking them more accurately to ecological impacts by monitoring ecological attributes is also needed. Figure 4 illustrates how indicators in both models might be arranged according to their applicability in different spatial and temporal scales.

Joint Implications of the Terrestrial and Aquatic Conceptual Models

Although attributes are frequently affected differently in the two models, there are some indicators of ecological health that are good measures of change for both systems. Acid deposition causes changes in soil chemistry and soil leachates that, in turn, affect water quality in streams as well as nutrient availability to plants and habitat for soil biota.

Terrestrial and aquatic biotas are consequently stressed. Many indicators related to this soil and water acidification process exist. A few of the simpler and higher priority indicators are: acidity of stream water or soil leachate (recognizing seasonal and precipitation event variations), soil cation exchange capacity, aluminum concentration (or Al:Ca ratios) in streams, or conductivity.

Similarly, ozone and ultraviolet radiation stresses may occur for aquatic, amphibian, and terrestrial biota. Although direct measurements of ozone and UV-B are needed, simple monitoring of vulnerable species for health effects, or population changes is important. Air emissions also relate to heavy metal accumulations in soils and streams. Tissue analysis to determine bioconcentration of toxic compounds in selected higher trophic level biota may be warranted.

An additional link between the two models is at the physical interface between aquatic and terrestrial systems. Many kinds of changes in these habitats can have far reaching ecological ramifications. Changes in land use patterns around and within parks affect storm water runoff (water quality and quantity), habitat connectivity (re-establishment of locally extirpated native species), vulnerability to invasive species, and damage risks from fire, chemicals, and air quality. Direct diagnostic measurements of parameters associated with patterns of land use change are needed. Non-diagnostic indicators to monitor include loss in park native species diversity (terrestrial or aquatic guilds of species), change in stream flow in response to storm and drought events, invasive species presence/dominance in riparian areas, and human population growth.

What makes a good indicator?

Characteristics of good vital signs, and how they may be categorized are:

1) Easily and non-destructively measured
2) Sensitive to stresses
3) Anticipatory
4) Respond to stress in a predictable manner
5) Clearly connected to the functions it reflects
6) Have a known response to changes over time
7) Have low natural variability
8) Indicative of significant ecosystem changes
9) Integrative

CATEGORIES OF VITAL SIGNS	
Stressor indicators	Measures of the stressor itself; eg. Amount of pollution emitted at the source; drawback=no indication of the ecosystem consequences
Exposure indicators	Amount of stressor to which the ecosystem is exposed
Response indicators	Changes that occur in the ecosystem; eg. deformities in amphibians
DIAGNOSTIC INDICATORS are specific to a given stressor and tend to be retrospective **NON-DIAGNOSTIC INDICATORS** may be elicited by many types of stressors and may provide early warning of ecosystem distress	

(Dale 2001, Jope 2001, and Environment Canada 2000)

Research Questions

Some of the research questions associated with monitoring the ecological health of park units in the Cumberland-Piedmont and Appalachian Highlands Park Networks, include:

What are the long-term ecological impacts of anticipated atmospheric deposition on high and mid-elevation soils, native vegetation, and water quality? These are landscape-level questions, for which systematic research across the region is necessary. Short- and long-term ecological impacts of frequent high ozone events are believed to be substantial but specific documentation on ecological functions and effect to species groups is not available.

What are the ecological impacts from invasive species on native ecosystem functions and biodiversity? Because ecological links are not clear, the ecological costs of invasive species infestations have not been established. Such research would help provide information needed to develop strategies for control of invasive species, and for ecosystem restoration in those areas already impacted.

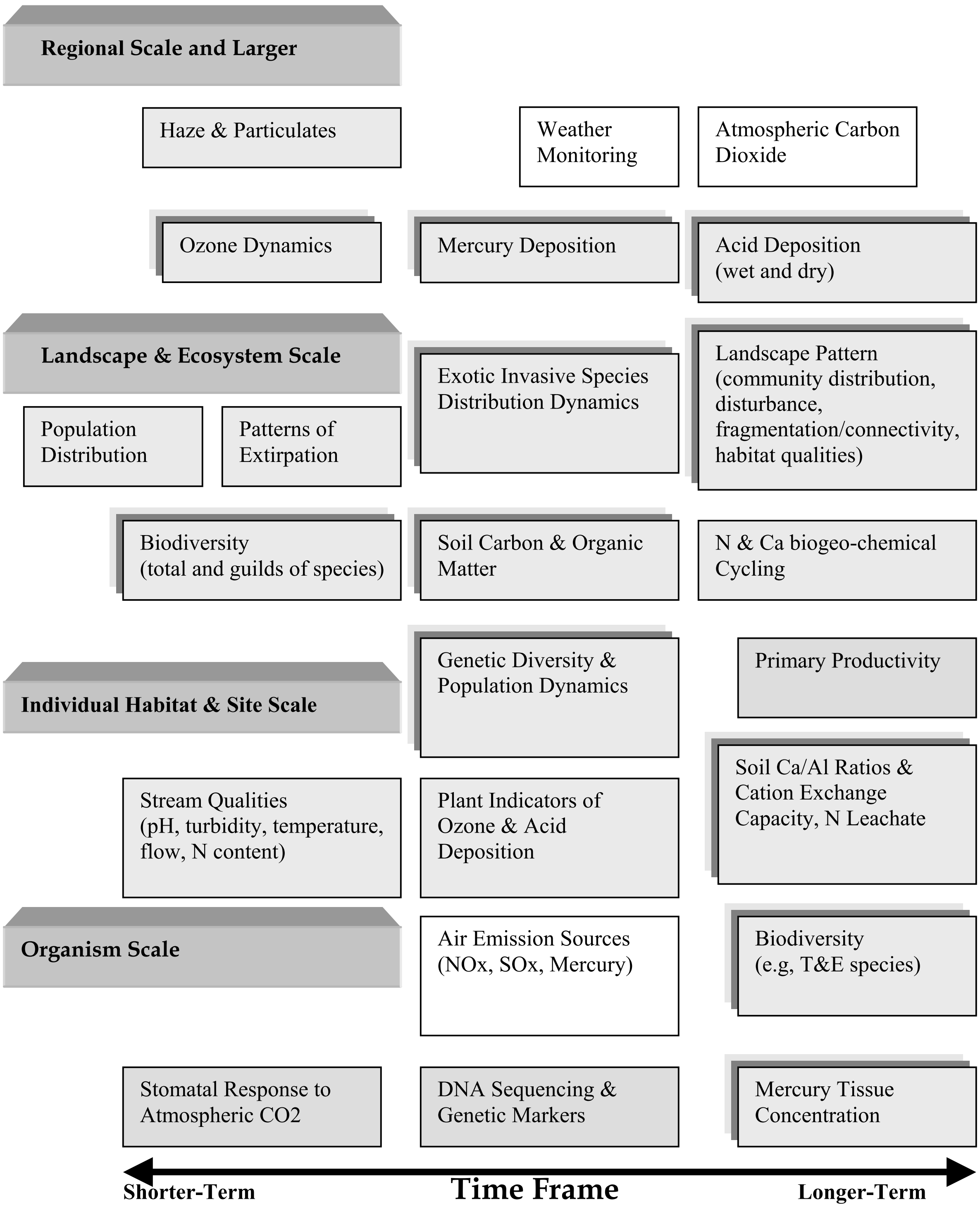
What is the genetic diversity within isolated populations of rare species? In view of increasing habitat fragmentation, we know little of how best to manage remaining populations.

What is the capability, practicality, and effectiveness of restoring small habitats (i.e., for small parks) in light of increasing isolation from other similar habitats and impacts from pollution, invasive species, and direct human impact? What level of restoration or attainment of target ecological conditions is reasonable to work toward?

What are the cumulative effects of various stressors and modified disturbance regimes? Some may act synergistically but these synergisms can only be guessed at.

What relationships exist between ecological health and soil biota diversity, composition, structure, and biomass? This includes both macrofauna and micro-organisms, many of which have not been studies for their relationship with various ecosystems, habitats, and their recovery or response to stresses and disturbances.

Figure 4. Organized by geographic and time scales are ecological health indicators (potential vital signs) of most concern or most repeated for diverse ecological purposes. Darker boxes indicate greater significance. Lightest boxes are monitored by others.



List of Potential Indicators for Ecosystem Health Changes

Air Quality
- Atmospheric ozone concentration/dynamics
- Sulfur and nitrogen wet and dry atmospheric deposition in selected ecosystems/locations
- Indicator terrestrial and aquatic biota damage from various pollutants (ozone, volatile organic compounds, acid deposition, mercury)
- Stream acidification
- Stream Al:Ca ratios; cations:anions
- Soil acidification along with acid neutralizing capacity
- Tissue analysis (e.g., mercury)
- Nitrogen concentration in streams
- Mercury deposition (soils, sediments)

Weather - storm severity, frequency, timing

Biogeochemical Cycling
- Nitrogen
- Calcium
- Aluminum
- Potassium, Magnesium, Phosphorus
- Selected micronutrients

Water Quality, Quantity, and Surface Runoff
- Stream Ph/acidity and acid neutralizing capacity
- Turbidity and siltation
- Flow and discharge rates during weather events
- Dynamics of water quality characteristics during weather events and over years and decades (especially low flow and high flow periods)
- Organic and inorganic contaminants
- Primary productivity
- Dissolved oxygen
- Water temperature
- Water conductivity and salinity
- Nitrogen
- Aluminum
- Coliform count

Stream Habitat Qualities
- Transport and deposition rates of sediments as well as effects of these on the non-sediment substrate structure.
- Stream substrate and physical habitat changes; channel and drainage morphology
- Stream sediment as it relates to structure, distribution, and chemical composition (metals, organics, and toxics which, in various forms, would originate with pesticides, herbicides, solvents, etc.)

Stream Biota
- *Algae and Plants:* diversity, abundance, distribution, and community structure. Community structure monitoring would involve the tracking of selected species populations and population trends.
- *Bacteria:* diversity, abundance, harvest levels, distribution, and selected species of interest.
- *Zooplankton:* diversity, abundance, distribution, and community structure. Community structure monitoring would involve tracking particular species for their number, change, distribution, reproduction, development, and relationship to other species and species groups.
- *Macroinvertebrates:* diversity, abundance, distribution, and species performance with respect to reproduction, development, and relationship to other species. Particular groupings of species are mollusks, insects and arthropods, annelids, and others.

Fish: Diversity, abundance, distribution, and community structure for selected species. Population performance with respect to reproduction, development, and population structure is relevant. The same applies to:

Amphibians/Reptiles: see "Macroinvertebrates"

Birds: see "Macroinvertebrates"

Mammals: see "Macroinvertebrates"

Other Potential Indicators: links between taxa, mass balance of nutrients, energy flow, and parasite loads in various species.

Tissue-Level Accumulation of Metals and Toxics

Detritus and decomposition including litter build-up and decomposition rates

introduced, exotic, and sport species population structure, performance, dynamics; threatened and endangered species and the resources that support them.

- Soil Changes
    - Nitrogen status, leaching
    - Carbon content
    - Acidity and cations
- Terrestrial Sight and Noise Environment Changes
    - Change in noise levels and types
    - Night light levels
- Terrestrial Biota
    - Change in vegetation maps
    - Change in development elements on maps
        - Forested:cleared habitat ratios
        - Impermeable surface area
    - Biotic interactions for selected species
    - Soil macrofauna composition, diversity, biomass
    - Soil microbiota composition, diversity, biomass
    - Species population changes and changes in dynamics
    - Species population distributions
    - Species richness and biodiversity
        - Disappearance of species from plots
        - Changes in biodiversity indices
    - Productivity
        - Primary productivity
        - Net primary productivity
        - Nitrogen concentration/turnover
    - Habitat condition (in response to restoration)
    - Invasive exotic species
        - Number of new species detected
        - Change in distribution of existing species
        - Feral animals (presence and numbers)
    - Threatened and endangered species
        - Change in groups of T&E species
    - Genetics diversity and interaction of populations
        - Small population genetic diversity (viability)
        - Large population diversity and distribution of sub-populations
        - Changes in genetics of guilds of species
    - Trophic structure/function changes
        - Biomass of species guilds
        - Predator dynamics
        - Herbivore population dynamics
    - Toxics accumulation
        - Selected species tissue analysis
    - Succession
        - Species composition
        - Understory regeneration species composition

Exotic invasive plants, pests, diseases, pathogens
Change in community structure
Relative and absolute numbers of selected species
Change in species/habitat arrangements/landscape patterns
Changes in amount of edge
Edge to area ratios
Size of habitat islands and distance between
Patterns of species extirpation
Permeable and impermeable land surfaces
Off-park Data
Permitting applications
Fishing and boating use rates, number of swimmers
Measures of herbicide, pesticide, fertilizer use/application (agriculture)
Measures of farm and domestic fuel use
Measures of cattle, pigs, fowl, and cumulative populations in area
Building and septic tank permits
Visitor-use surveys on park
Real estate and market estimations

Prioritizing Potential Indicators for Vital Signs Designation

It is suggested that a small interdisciplinary group review the full list of potential indicators. In the review, each potential indicator should be compared to every other indicator using problem-solving/decision-making tools. From this process, the top 10% to 20% of the indicators should be selected for further scrutiny as potential ecological vital signs. The conceptual ecological models should aid in identifying those indicators most worthy of vital sign designation

Phase I Conclusions

The CPN made good progress toward meeting Phase I objectives to develop a Board of Directors and technical committee, compile and summarize existing information on park resources/issues, and to develop draft conceptual models. The Water Quality Monitoring Plan and Quality Assurance Plan are completed and under review. However, there is still a lot of work to do before Vital Signs are selected and the time allotted for Phase II is likely not enough. First of all, a decision making process needs to be established. Approaches among networks have ranged from university run websites with sophisticated analytical software, to workgroup sessions with locally derived ranking sheets. With CPN the latter process would seem to be best. Taking advice from one Vital Signs expert, Kathy Jope, the ranking process worked better in two steps. Rank the "management" and "ecological" significance of the "stressor/effect" first, followed by another round of ranking to establish "what makes the best indicator" (Craters of the Moon NM, worksheet comments,by Kathy Jope. IM Handouts, August 2001). The CPN has conducted the first round of ranking issues by management significance but now needs to incorporate ecological significance (aided by the conceptual models process) prior to "Vital Signs" selection. This will be accomplished by establishing an interdisciplinary workgroup to hold a scoping workshop the first of next year. If possible (ie.,time is allowed) a lead scientist will be assigned to focus on the indicator selection stage and will follow through with protocol development during Phase III. With assistance from the Mammoth Cave LTEM program, the existing CESU, and several new CESU members coming on board in Winter 2002/03 (including 3 universities near the Mammoth Cave CPN Office), it should not be a problem to staff an interdisciplinary workgroup.

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